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PROGRAM IN INFORMATION POLICY

ENGINEERING-ECONOMIC SYSTEMS DEPARTMENT

STANFORD UNIVERSITY • STANFORD, CALIFORNIA 94305

RESEARCH ON THE APPLICATIONS
OF SPACE TECHNOLOGY

(Final Report)

October 1979

National Aeronautics and Space Administration

Contract NASW 3204

PROGRAM IN INFORMATION POLICY

Engineering-Economic Systems Department
Stanford University Stanford, California 94305



Abstract

Seven individual reports are included in this final report as follows:

- "An Illustrative Analysis of Technological Alternatives for Satellite Communications," Murray R. Metcalfe, Edward G. Cazalet, D. Warner North, Report No. 24, Oct., 1979.
- "Economic Aspects of Spectrum Management," Robert D. Stibolt, Report No. 25, Oct., 1979.
- "Cost Comparison of Competing Local Distribution Systems for Communication Satellite Traffic," Frederick E. Dopfel, Report No. 26, Oct., 1979.
- "The Economic Basis for National Science and Technology Policy," Donald A. Dunn, Report No. 23, Oct., 1979.
- "An Inquiry Into The Household Economy," Ralph D. Samuelson, Report No. 22, Oct., 1979.
- "Government Patent Policy: An Analysis of the Effects of Three Alternative Patent Policies on Technology Transfer and the Commercialization of Government Inventions," Mark Matousek, Report No. 27, Oct., 1979.
- "Improving NASA's Technology Transfer Process Through Increased Screening and Evaluation in the Information Dissemination Program," Horstfried Lapple, Report No. 28, Oct., 1979.

These individual reports are available separately from the Program in Information Policy, Department of Engineering-Economic Systems, Stanford University, Stanford, CA 94305

Contract NASW 3204

July 1, 1978 through Sept. 30, 1979

On-campus program initiated October, 1978

Off-campus program (Washington, D.C.) initiated July, 1978

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Final Report Overview

This report is a collection of seven reports that relate to the theme of the research under this contract: the applications of space technology. These reports describe the research done by students and faculty at Stanford and by interns in Washington during the first year of the contract. Our procedure has been first, to prepare working papers which are discussed with interested individuals at Stanford, NASA, and the Senate Subcommittee Staff, and then to prepare reports of the type incorporated in this final report.

The reports here center around two major subjects: communication satellites and technology transfer. The communication satellite area is represented here by three reports: (1) an analysis of NASA's technological alternatives in this field; (2) a report on the economic aspects of orbit-spectrum allocation; and (3) a report on the cost structure of local distribution systems for satellite communication. The first report, on technological alternatives, has been prepared on the assumption that the orbit-spectrum resource will continue to be allocated to communication satellite service providers at zero price. The second report questions this assumption and examines policy options that would place a nonzero price on this resource as a technique for achieving increased economic efficiency

in the use of this resource. The third report is a brief exploration of the cost structure of local distribution of satellite signals, a subject that strongly affects overall satellite system design. One of our conclusions from this work is that all three of these subjects are closely linked. There is a need for future research on R&D project selection that takes into account the possibility that the orbit-spectrum resource will be used more efficiently than would be the case under present FCC rules. There is also a need for further study of orbit-spectrum management techniques that takes more full account of satellite system design and the expected future evolution of satellite system technology.

The reports related to technology transfer in this volume are: (1) a broad analysis of the economic basis for national science and technology policy; (2) a study of the economics of the household economy; (3) a study of government patent policy; and (4) a study of screening and evaluation in information dissemination. The first paper provides an overview of the entire area of science and technology policy, with a view to obtaining an understanding of the place of technology transfer policy in science and technology policy generally and of some of the broad policy options in both technology transfer and other areas of science and technology policy. The report on the household economy is a detailed study of a specific question that

arose in the study of science and technology policy. Just how important is the household economy in comparison with the market economy? Most science and technology policy studies have been focused on growth in GNP and on productivity in the market economy. An interesting result of this household economy study is that the household economy is comparable to the market economy in size and importance. This result raises a number of questions about the relevance and validity of policy studies that do not take the household economy into account at all. The study of government patent policy was conducted by an intern serving on the staff of the Senate Subcommittee and is intended to provide a broad picture of this area. The report on screening and evaluation in information dissemination represents the results of a preliminary study of this aspect of NASA's technology transfer program. Our preliminary work in this field suggests the need for a more comprehensive and in-depth study of the management options in this field.

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AN ILLUSTRATIVE ANALYSIS OF TECHNOLOGICAL
ALTERNATIVES FOR SATELLITE COMMUNICATIONS

Murray R. Metcalfe
Edward G. Cazalet
D. Warner North

National Aeronautics and Space Administration

Contract NASW 3204

October 1979

Report No. 24

PROGRAM IN INFORMATION POLICY

Engineering-Economic Systems Department
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ABSTRACT

There are several indications that the demand for satellite communications services in the domestic market will soon exceed the capacity of the satellites currently in place.

Two approaches to increasing system capacity are the expansion of service into frequencies presently allocated but not used for satellite communications, and the development of technologies that provide a greater level of service within the currently-used frequency bands. This paper is directed towards the development of economic models and analytic techniques for evaluating capacity expansion alternatives such as these.

The first part of the paper provides a brief overview of the satellite orbit-spectrum problem, and also outlines some suitable analytic approaches. This is followed by an illustrative analysis of domestic communications satellite technology options for providing increased levels of service. The analysis illustrates the use of probabilities and decision trees in analyzing alternatives, and provides insight into the important aspects of the orbit-spectrum problem that would warrant inclusion in a larger-scale analysis. Finally, the application of such analytic methodologies to the examination of satellite R&D decisions such as those faced by NASA is discussed.

Section I

OVERVIEW OF THE APPROACH

1. Introduction

This paper begins the development of economic models and analytic techniques for evaluating NASA communications-satellite R&D decisions. First, a brief overview of the communications satellite orbit-spectrum problem is provided. This overview describes the need for structural economic models that characterize both the systems demand for satellite communications services as well as the supply of such services under a wide range of technology and policy options. The overview also describes the need for methodology to analyze NASA communications satellite R&D alternatives, taking account of considerable market and technology uncertainty.

The second part of the paper provides an illustrative analysis of U.S. domestic communications satellite technology options for providing increased levels of domestic communications services within the constraints of orbit geometry and present frequency spectrum allocation to domestic communications satellites. The analysis illustrates the use of probabilities and decision trees in analyzing technology alternatives and provides insight into the important

aspects of the orbit spectrum problem that must be dealt with in a full-scale analysis.

The final section of the report outlines how analyses of the type described in the preceding section can be used to examine satellite R&D decisions such as those faced by NASA.

2. Background

The allocation of geosynchronous orbit positions and frequency spectrum to communications satellite use is a complex technical, economic and political problem. The U.S. domestic market will be considered in this discussion as an illustration of these problems.

There are presently three frequency bands allocated to U.S. satellite communications: 4/6 GHz (C band), 12/14 GHz (Ku band), and 20/30 GHz (Ka band). Interference considerations limit the use of the geosynchronous arc, and projections of demand growth indicate that the orbit-spectrum capacity in the C band and Ku band will be fully utilized within a few years. The Ka band is not yet utilized for satellite communications and presents some technical and cost disadvantages relative to the C and Ku bands. One option for expanding domestic satellite communication services is to pursue development of Ka band capability.

In addition to increasing the amount of orbit-spectrum allocated to communications satellites, there are many

technical alternatives for providing greater services within a fixed orbit-spectrum. These technical alternatives include changes in satellite and earth station design involving signal processing, antenna design including polarization, demand assignment among a pool of satellites, use of spot and inter-satellite beams and changes in interference design parameters. These technical alternatives offer the possibility of a several-fold increase in communications services for a fixed amount of orbit-spectrum resource.

The demand for domestic communications satellite services has expanded rapidly. In some cases communications satellites have diverted voice and data communications from possible new, more costly terrestrial communications capacity. In other cases, the increasing economic advantage of communications satellites has reduced the costs of long-distance communications, particularly video, and has resulted in the development of new communications services that would otherwise have been uneconomic.

It is very difficult at this time to foresee what balance or imbalance will result between the technical alternatives for expanding orbit-spectrum capacity and the demands for communications services. Moreover, the demand depends on the costs of satellite communications services in relation to the costs of terrestrial communications and the benefits of additional communications. In addition the balance is sensitive to current R&D decisions to develop technology as well

policy decisions to change the allocation or price of the orbit-spectrum.

3. NASA's Role

NASA's role in developing new satellite communications technology is articulated in recent testimony of Associate Administrator Anthony L. Calio before the House Subcommittee on Space Science and Applications.¹ NASA plans to meet the need for improved effectiveness and efficiency in the use of the limited resources of the radio spectrum and geosynchronous orbit positions by:

- 1) new technologies to expend the capacities of existing bands, and
- 2) capabilities for functioning in the unused Ka band.

In the first category fall "frequency re-use" methods involving contourable-beam space antennas, onboard switching, signal modulation, and polarization techniques. NASA proposes to take a leadership role in developing these technologies for the Ka band:

We propose to develop an understanding of Ka-band usage within a multibeam antenna research effort. We believe that a unified R&D effort built around these new technologies and techniques will best advance U.S. leadership in satellite communications and support industry's efforts to increase the capacity of the two lower-frequency commercial bands (C-band and Ku-band). Simultaneously, this activity will provide new information and confidence in equipment for Ka-band use for private commercial purposes. We have widespread, enthusiastic acceptance from the industry on these plans.

A. J. Calio, Testimony of
February 20, 1979, p. 23

In addition to its role in R&D, NASA provides technical advice to the FCC on spectrum allocation and equipment technical specifications. This role places NASA in a position to participate in a wide range of potential policy decisions on the mechanisms by which frequency usage will be regulated.

Finally, although NASA's role in the regulation of orbit-spectrum usage is limited to technical advice, it is necessary for NASA to take account of the effect of future regulatory policy on the need for new capacity and technology. For example, government policy mandating or encouraging frequency re-use or conservation measures could have a major impact on the need for NASA's R&D on Ka band technology.

4. A Framework for Analysis

Decisions such as those associated with NASA's role in satellite communications are very difficult. While considerable information on the technology and market is available, not all of it is relevant or reliable. Many technology and policy alternatives are possible, but it is very difficult to comprehend the important interactions among the alternatives. And, even if one could project with certainty the outcomes of alternatives, there is still the problem of determining what we want or who is to pay the costs and share in the benefits.

At the beginning we must recognize that no forecasting or other analytic methodology can eliminate uncertainty, make

decisions or replace the need for difficult value judgments. Rather, analysis and models are useful in the decision process if they facilitate the decision process in structuring available information and value judgments or preferences in a way that provides insights into the choices among alternatives.

The objective, therefore, is to work towards the development of a process of analysis that is supportive of the NASA decision processes and makes appropriate use of models and analysis.

5. Decision Analysis

Many aspects of communication satellite orbit-spectrum decisions can be captured using readily understood techniques of decision analysis.² In particular, the supply and demand for satellite communications services are highly uncertain, as are the technical outcomes of R&D. Early resolution of technical uncertainty through R&D can have an immediate beneficial effect on the market by facilitating good decisions on the design and development of new satellites and the use of the orbit-spectrum resource. The techniques of decision analysis provide a way to put a dollar value on the benefits of resolving uncertainty through R&D, thus allowing the costs of R&D to be rationally compared with the benefits.

Decision analysis is more than an analytical technique for characterizing uncertainty in a decision problem. It is also a process of analysis for bringing policy and technology

decisions into a logical relation with the available information, alternatives and preferences.

Typically a decision analysis is carried out with the close involvement of many technical specialists and the responsible executive officials. Through an iterative process of information structuring and alternative generation, a sequence of analyses is performed. The end product is not the analysis but is the insight and communication that is achieved by the participants in the analyses. This process has been successfully demonstrated in many public and private decision settings involving R&D, public regulatory policy, corporate new product decisions, environmental planning and facility capacity expansion.

As a first step towards such an application of decision analysis to communications satellite R&D and policy decisions of interest to NASA, we have developed the illustrative example in Section II of this paper.

6. Structural Modeling

One of the aspects of the decision analysis approach that deserves special attention in the case of satellite communications planning is the complexity of the interactions among the competing satellite and terrestrial communications systems and the demands for communications services. For example, as the cost of communications is reduced by technological advances, new demands for communications services appear. These demands cause the capacity of existing systems to be fully utilized

and create a need for new systems that compete for scarce spectrum and orbital positions with existing systems.

Attempts to use simplified models of the communications market are generally not very satisfying. A typical approach is to forecast the magnitude of future communications demand categorized by type of communication, video, data, voice. But in a world where the distinctions between different communication techniques are becoming fuzzy and where the costs of communication, including travel and mail, are changing rapidly, forecasts that extrapolate from past demand data are not very accurate or useful.

A modeling approach that has been applied successfully in many industries is a structural modeling approach. In this approach, the demands for communications are characterized in terms of basic end-use services such as person-to-person and broadcast communications and in terms of the time urgency and content of information to be communicated. Specific end use market segments, such as residential, large business, and small business might be distinguished.

The alternative communications modes, such as voice, video, data, mail, and travel, available to each end-use would be identified and the demands for each derived from the basic end-use data and the prices charged for each service. These prices would be computed with bases of information characterized in the supply side of the model.

Communications services can be provided by a large number of alternative technologies. Each of these technologies has its own unique resource requirements in terms of spectrum resources, capital resources, reliability, and types of communications that can be carried out. The prices of these services are generally determined in part by economic forces and in part by a regulatory policy that allocates scarce public resources and controls prices of some services. These prices and the regulatory policies determine which technologies are developed and utilized to meet demand. The prices charged for the communications services in turn influence demand as described earlier.

In a structural model of the communications market, each generic communications technology would be identified, and the direct capital operating and other costs associated with each unit deployed would be characterized as inputs to the model and would be adjusted within the model to account for inflation and technological learning effects. In addition, the technical information required to compute the amount of spectrum and orbit resources required for a given mix of communications services would be provided.

The model would utilize this and other information to simulate the expansion and operation of an entire communications system including all major forms of communications over a period of twenty or more years. The model calculations

would be carried out iteratively because of the simultaneous nature of the interaction between supply, demand and prices.

A structural model of this type would allow investigation of the penetration of different technologies under a variety of assumptions regarding the outcomes of R&D and public communications regulatory policy. Such a model would also be a useful tool for investigating alternative communications satellite regulatory policies.

In this paper we have not attempted any significant structural modeling of the communications market and have instead relied on existing forecasts as a basis for the illustrative decision analysis. This lack of emphasis on a structural model of the communications market should not, however, be taken as an indication of the lack of a need for such modeling. The illustrative example as developed in this paper makes clear the need for better models of the communications market as an aid to communications satellite R&D planning.

Section II

THE ILLUSTRATIVE ANALYSIS

1. Introduction

This section of the paper describes an illustrative application of decision analysis to technology decisions affecting domestic communications satellites. First we examine the likelihood of satellite services demand exceeding the system capacity in the future. Having shown the uncertain need for additional capacity, two options for increasing orbit-spectrum capacity are discussed and compared: the development of conservation and re-use technologies for the frequency bands currently in use, and the introduction of service at a higher frequency band (the Ka or 20 to 30 gigahertz band).

Background information for the analysis is provided by four contractor reports, supplied by NASA. The contractors are Western Union and ITT, whose studies concentrate on the demand for Ka band satellite services, and Hughes and Ford Aerospace, who provided "systems studies" of the technical and cost details of alternative Ka systems.

The first part of the analysis develops a simplified demand model, based largely on the ITT analysis. ITT's forecasts are presented and discussed. Then a probabilistic version of the ITT forecast is developed, based on a set of illustrative estimates by the authors. The next section of

the paper examines system capacity. Again the deterministic data from the ITT analysis are used as a base on which to build a probabilistic forecast. The probabilistic forecasts for demand and capacity allow us to examine the question of system saturation in a decision analysis framework.

The next section of the paper considers system expansion through the use of a Ka band service or frequency re-use. A series of scenarios demonstrate how the technologies might be used to meet demand. The comparison of technological alternatives through the use of cost information is discussed and an illustrative cost comparison of Ka service to re-use is presented.

2. Demand

A forecast of the future demand for satellite services is essential to any evaluation of alternative satellite systems. Ideally, the demand model would build a forecast by aggregating over the various types of service. In keeping with a decision analysis approach, the explicit consideration of uncertainty would be desirable.

Below we develop a simple model of demand. We first develop a framework for a general satellite demand model. The model is derived largely from the ITT analysis. ITT's data and results are briefly discussed. In the latter part

of the section we develop a probabilistic forecast, using a set of illustrative probability distributions.

The data developed in the Western Union report is in a different form from that used by ITT, and is not used in our demand model. The Western Union data is presented and compared to the ITT data in Appendix A.

Outline of a General Satellite Demand Model. A framework for a satellite demand model is shown in Figure 1. The model estimates satellite traffic in equivalent transponders for a given service (voice, data, or video) in a given year.

We would expect the demand model to be driven by price, which in turn will depend to some degree on the cost of both terrestrial and satellite technologies. The model then determines the total annual demand for long-haul telecommunications traffic. However, of greater interest is the peak level of telecommunications traffic. This will depend on total traffic load, and also on peak hour pricing strategies. The peak demand will determine the capacity requirements.

The next step is to determine the satellite share from the total peak demand. We can think in terms of a "satellite capture ratio," or market share, that determines the percentage of the total demand that goes to satellites. This ratio will vary for different types of service. The major factor in determining this ratio for a given type of service are the relative costs of terrestrial and satellite technologies for a transmission of a given distance. Finally, the average

FOR A GIVEN YEAR
AND TYPE OF SERVICE

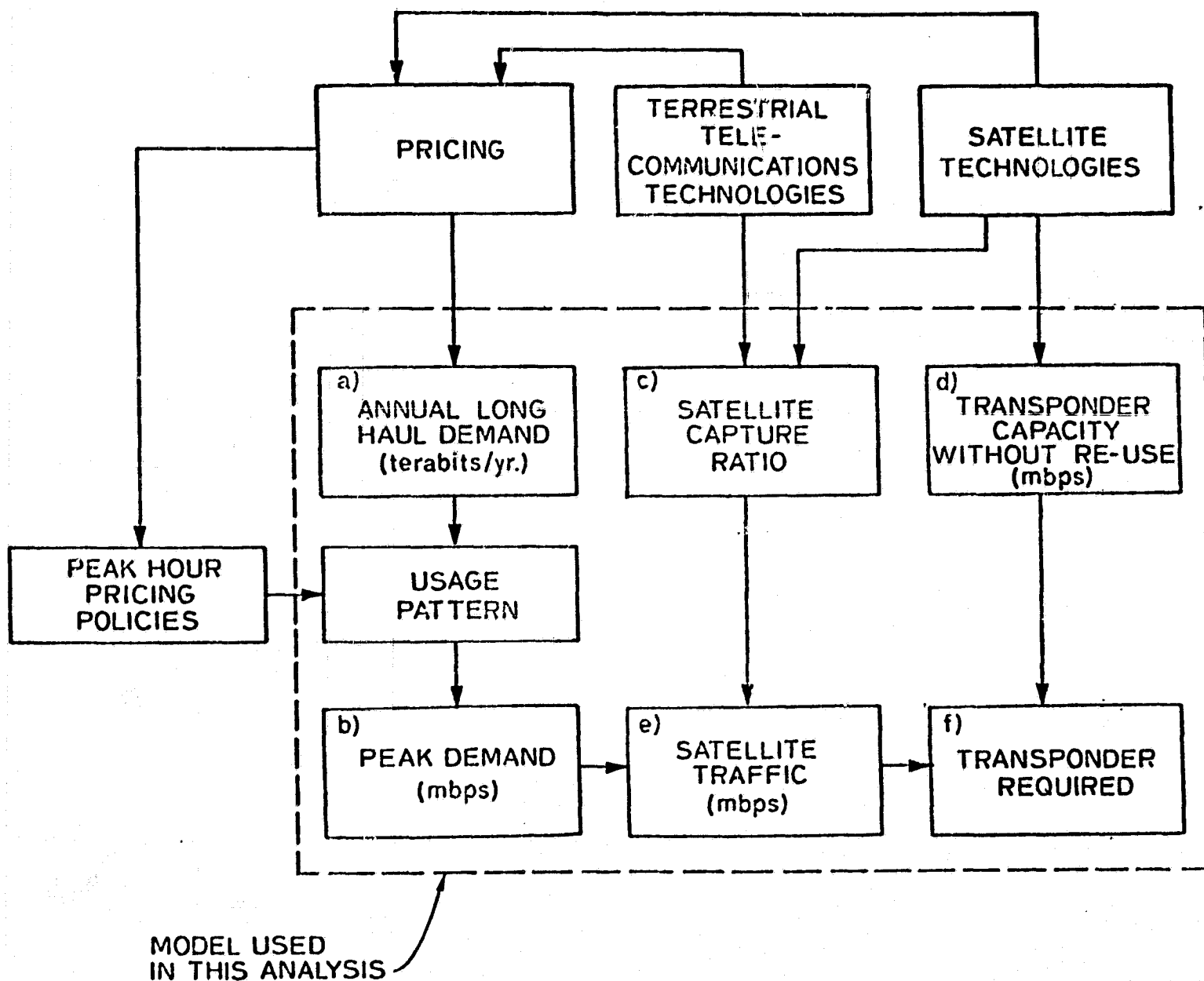


Fig. 1: Framework for Satellite Demand Model

capacity of transponders in use will determine the demand for transponders.

A More Limited Demand Model. The ITT analysis does not explicitly consider price as a factor in demand. Presumably the assumption is that demand is simply not price sensitive, or that price can be determined directly from satellite systems cost estimates and from projections of terrestrial tariffs. This leads us to a simpler demand model, which is shown within the dotted lines in Figure 1. Price and cost characteristics of terrestrial and satellite technologies are considered implicit to the resulting model.

Below we discuss the components of the modified model, and present the relevant data from the ITT report.

a) Yearly Long-Haul Demand. ITT's forecast of yearly demand for the years 1980, 1990, and 2000 is shown in Table 1. It is broken down into three services types: voice, data, and video. Note a common unit, terabits per year, is used for each type of service. The share of the traffic attributed to each type of service is also shown for each year.

b) Peak Demand. Peak demand determines the overall capacity required. Peak demand will depend on the overall traffic level, patterns of usage, and peak period pricing policies.

Table 2 shows ITT's forecast for peak demand, in millions of bits per second. The available

Table 1: ITT - Forecast of Yearly Demand, in Terabits/yr.

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	559,000 (74%)	1,402,000 (76%)	2,891,000 (77%)
Data	112,000 (15%)	281,000 (15%)	437,000 (12%)
<u>Video</u>	<u>82,500 (11%)</u>	<u>170,700 (9%)</u>	<u>417,300 (11%)</u>
Total	753,500 (100%)	1,853,700 (100%)	3,745,300 (100)

Table 2: ITT - Forecast of Peak Hour Demand (millions of bits per second)

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	43,800 (65%)	108,100 (63%)	204,700 (64%)
Data	20,667 (31%)	50,869 (30%)	78,853 (25%)
<u>Video</u>	<u>2,891 (4%)</u>	<u>13,252 (7%)</u>	<u>37,980 (11%)</u>
Total	67,358 (100%)	172,221 (100%)	321,533 (100%)

Table 3: ITT - Ratio of Peak Hour to Average Demand (Derived)

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	2.5	2.4	2.2
Data	5.8	5.7	5.7
Video	1.1	2.4	2.9

information gives no indication of the methodology used to determine peak traffic. For information purposes, the ratio of peak demand to average demand for each of the services is shown in Table 3.

- c) Satellite Capture Ratio. The satellite capture ratio refers to the percentage of long-haul traffic (defined by ITT as traffic transmitted more than 200 miles) that is handled by satellite. This will be different for different types of service.

ITT's capture ratios are presented in Table 4. The report does not state how the ratios were determined. One way of determining capture ratios is presented in the Western Union report. They consider the relative costs of satellite and terrestrial service to split the demand up. They develop a set of terrestrial/satellite crossover curves that determine the relative costs for various distances of transmission. However, the approach may still be simplistic. The ratio can also be different between sets of city pairs the same distance apart, depending on factors including traffic density, geography, etc.

- d) Satellite Traffic. Satellite traffic is an intermediate result. It is computed as the product of peak demand and the satellite capture ratio for each type of service.

Table 4: ITT - Satellite Capture Ratio, in percent

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	2	15	25
Data	1	50	60
Video	50	60	60

Table 5: ITT - Unit Transponder Capacity, in MBPS

<u>Year</u>	<u>Capacity</u>
1980	42
1990	72
2000	108

Table 6: ITT - Demand for Transponders (in 36 MHz equivalent transponders)

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	21 (34%)	225 (33%)	474 (42%)
Data	5 (8%)	335 (51%)	436 (39%)
<u>Viden</u>	<u>35 (58%)</u>	<u>110 (16%)</u>	<u>211 (19%)</u>
Total	61 (100%)	690 (100%)	1121 (100%)

e) Unit Transponder Capacity without Re-use Technologies.

ITT estimates that transponder capacity (in terms of bits received per time period) will increase as time goes on, as shown in Table 5. Because re-use technologies are not explicitly considered in the ITT analysis, we have assumed the capacity increases stem from factors other than the re-use technologies considered later in this report. Thus the data given in Table 5 are taken as base capacities, which can be increased by various re-use technologies.

f) Transponders Required. The resulting number of transponders required can be calculated as the quotient of satellite traffic and transponder capacity. ITT's forecast is shown in Table 6.

Probabilistic Analysis. Below we use the simple model outlined in Figure 1 and a set of illustrative probability distributions on the model components to demonstrate the construction of a probabilistic forecast. The output will be a probability distribution on total transponder demand for a given year.

The equation below determines the demand for a given type of service in a given year:

$$DT_{ij} = \frac{PKD_{ij}}{TC_j} \cdot SCR_{ij} \quad (1)$$

where: i = type of service: voice, data, or video

j = year

DT = number of transponders required

PKD = peak long-haul demand, in MBPS

TC = unit transponder capacity, in MBPS

SCR = satellite capture ratio

Below we will drop the subscript j . Just one year, 1990, will be considered.

The procedure to be used here will be to assign a probability distribution to each of the state variables. These can be transformed, through the use of equation (1) into a distribution on the number of transponders required for each type of service for 1990. This can further be converted into a distribution on the total number of transponders required.

Probability Distributions on Model Parameters. In general, a continuous or a discrete probability distribution can be assessed by one or more "experts" for each of the state variables. Techniques for the elicitation of distributions are well-established.³ The distributions we have used here are purely illustrative. In each case a discrete distribution with three branches is used. The value from the ITT report is

used as the "nominal" case and is assigned a probability of .5 . "Low" and "high" values, each with a probability of .25 are also assigned. The values assigned are shown in Table 7.

It can be expected that there is probabilistic dependence between certain sets of variables. In the first part of the analysis, where we produce distributions on demand for each of the three types of service, we assume there is no dependence between the peak demand PKD_i , the capture radio SCR_i , and the transponder capacity TC . It would in general be possible to include the dependencies by assessing conditional distributions, or by restructuring the model to include additional variables that explicitly deal with the dependencies, allowing unconditional assessments to be made.

Distribution on Transponders Required for Each Service Type. A probability tree, such as the one shown in Figure 2 for voice, can be constructed for each service. From the tree we can generate a probability distribution on the number of transponders required. The distribution has 27 branches. Because the distributions for voice, data and video traffic are intermediate results in terms of this analysis, they are not presented here; they are shown in Appendix B.

Distribution on Total Number of Transponders Required. It is also possible to use the assigned distributions to produce a distribution on total demand. This requires

Table 7: Probability Distributions for Demand Model for 1990

		Low (prob = .25)	Nominal (prob = .50)	High (prob = .25)
PKD	(Peak Demand)			
	- Voice (mbps)	86,480	108,100	140,530
	- Data (mbps)	25,434	50,869	76,303
	- Video (mbps)	6,626	13,252	33,130
SCR	(Capture Ratio)			
	- Voice	.10	.15	.25
	- Data	.4	.50	.65
	- Video	.45	.60	.7
TC	(Transponder Capacity) (mbps)	54	72	108

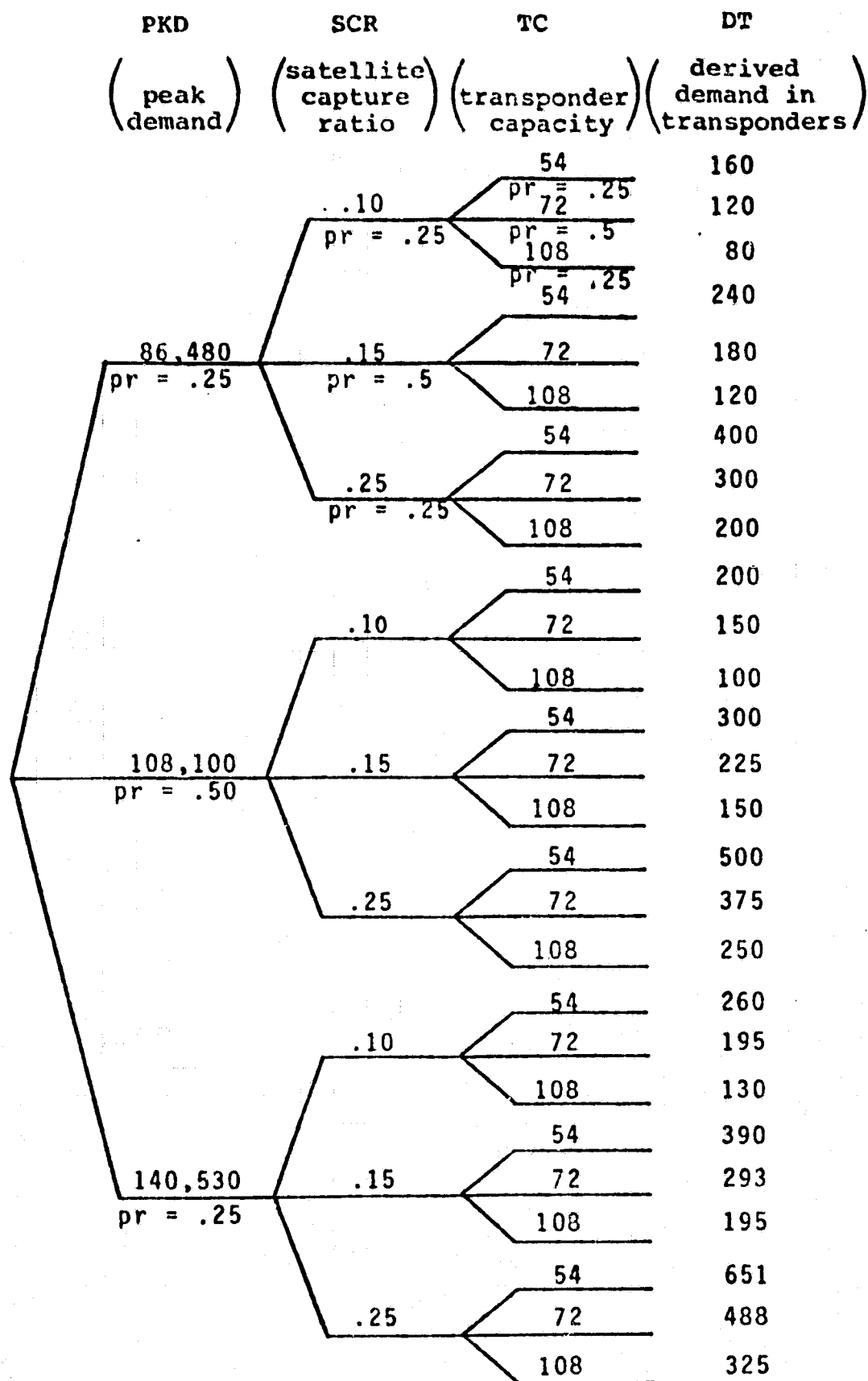


Fig. 2: Probability Tree for Voice Demand

further consideration of the dependencies between the types of service. Two possible approaches for the purposes of the demonstration are: 1) to assume independence between the peak demand for each service and between the capture ratio for each service; or, 2) assume complete dependence between the three peak demand variables, and complete dependence between the three capture ratio variables. The latter approach is used here. This means that if the voice peak demand variable takes on its low value, the data peak demand variable and the video peak demand variable also take on their low values. The same applies to the capture ratio variables. The assumption of complete dependence can be partially justified as follows. There are several common underlying factors that will influence peak demand for all the types of service. These factors include new developments in satellite technology, and general satellite service pricing policies. With respect to capture ratios, the most important underlying factor is the relative costs of satellite and terrestrial technologies; this should affect each of the three service types in a similar way. The fact that these underlying factors will influence the variables in a similar way for each type of service indicates that some dependence between demand for the three service types does exist.

The probability tree is shown in generic form in Figure 3, and the resulting cumulative distribution on total demand is shown in Figure 4. The point estimates from the ITT and WU reports are also shown.

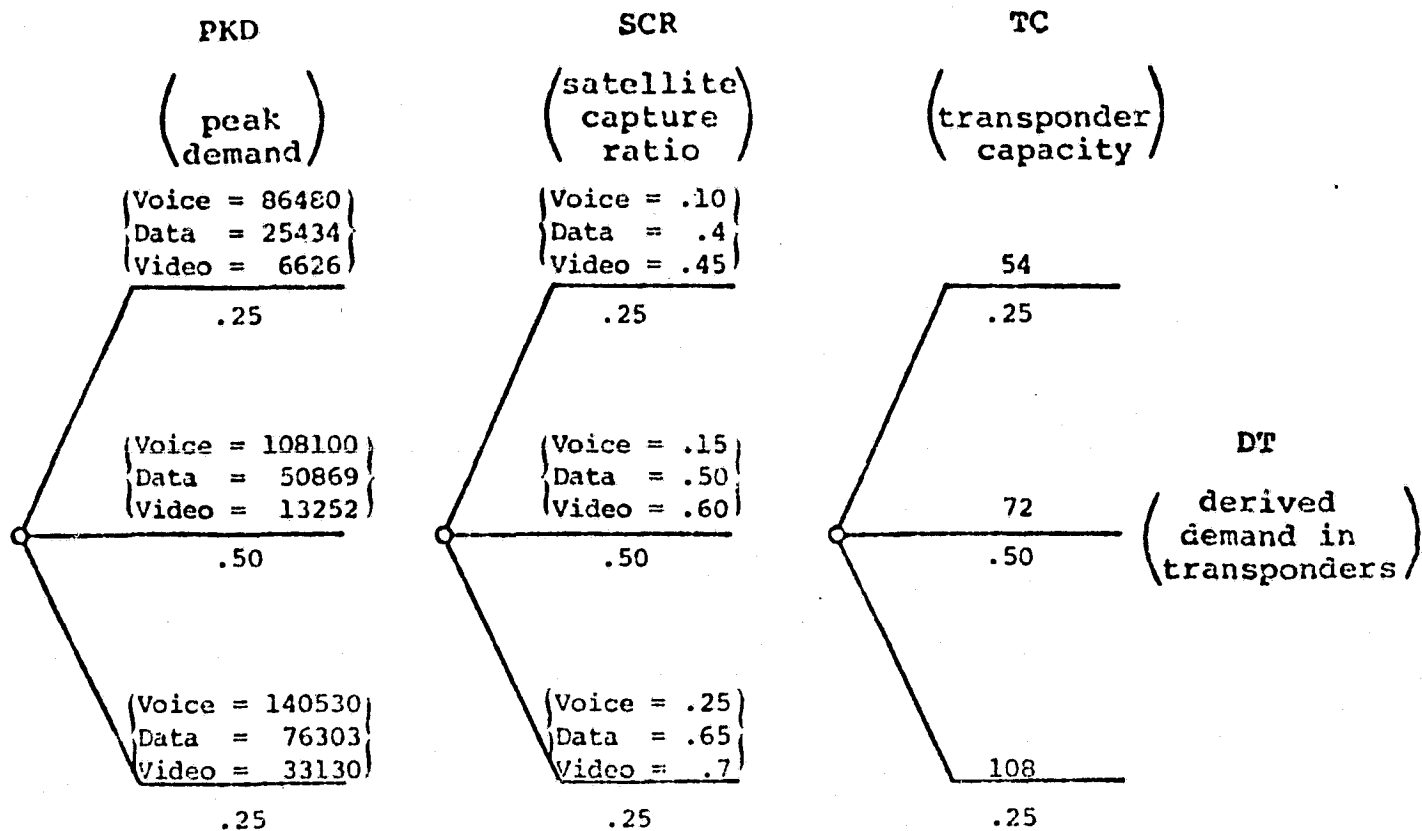


Fig. 3: Probability Tree for Total Demand

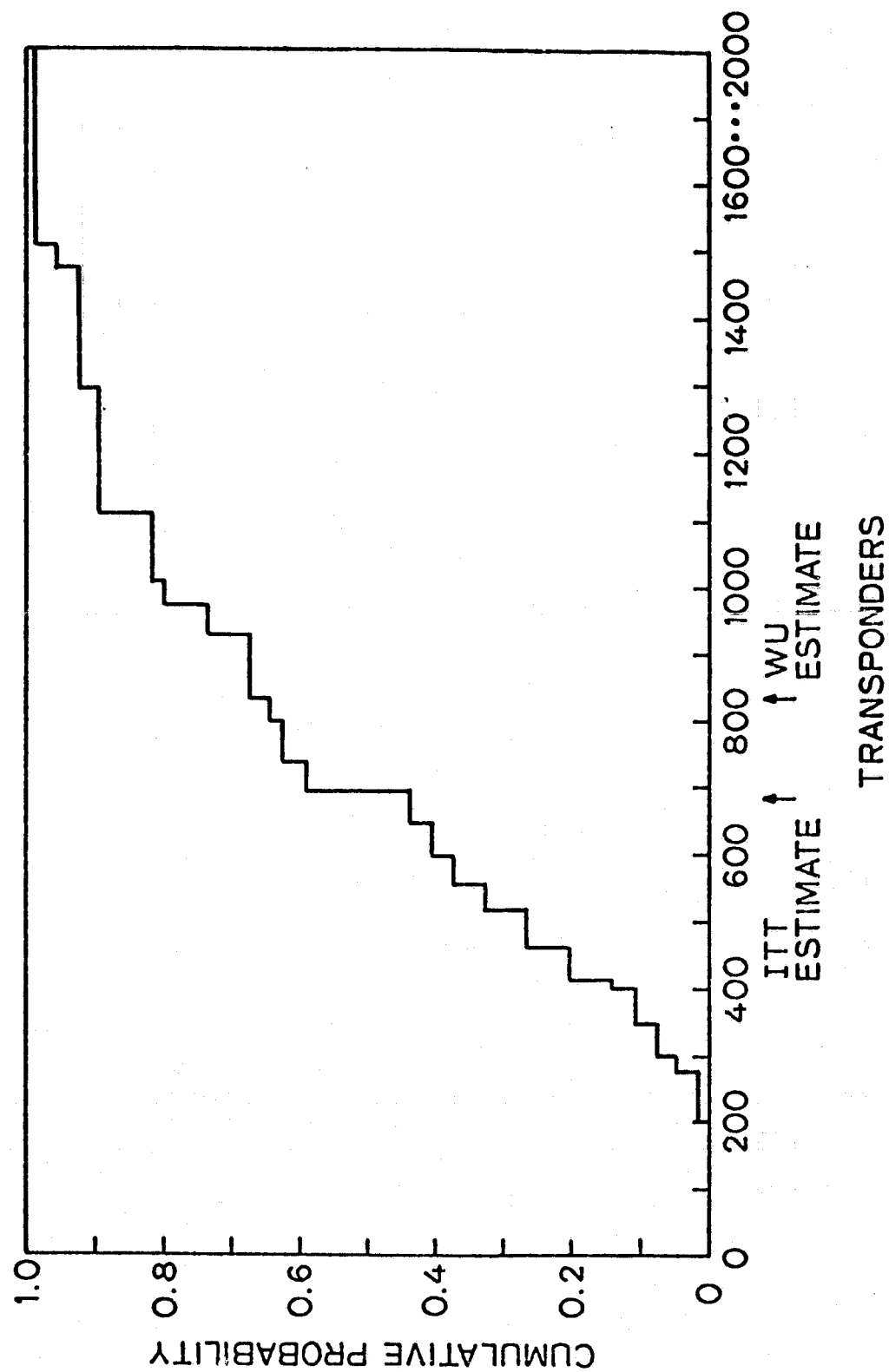


Fig. 4: Cumulative Distribution on Total Demand for Transponders in 1990

3. System Capacity Without Re-Use

In this section we determine the capacity of the domestic orbital arc, in terms of the number of domestic satellites and the resulting number of transponders that can be placed in orbit. The ability of each of the three frequency bands to handle communications traffic is limited by three factors:

- the intersatellite distance required to keep interference to acceptable limits--this determines the number of satellites that can be used;
- the number of transponders per satellite; and
- the fraction of the domestic orbital arc designated for use by the U.S.

The ITT report provides data on the first factor, and presents an estimate of available capacity. We first summarize that data. We then proceed in a manner analogous to that used in the demand section. We present a simple model that determines capacity from information on the three limiting factors listed above. We use the ITT data as a base from which to generate illustrative probability distributions on each of the factors. From these distributions we derive a probability distribution on capacity.

ITT Data

ITT presents three orbital spacing scenarios for the C and Ku bands. They are shown in Table 8. Although it is not explicitly stated, they appear to take 3° as the most likely Ka band spacing.

Table 8: ITT - Satellite Spacing Scenarios

<u>Scenario</u>	<u>C band</u>	<u>Ku band</u>
Minimum Capacity	4.5°	4.5°
Most Probable	4°	3°
Maximum Capacity	3°	3°

Table 9: ITT - Resulting System Capacities (in Transponders)

<u>Scenario</u>	<u>C band only</u>	<u>C and Ku bands combined</u>
Minimum Capacity	216	432
Most Probable	264	648
Maximum Capacity	384	768

The ITT estimates of C and Ku band capacities (in transponders) are shown in Table 9. They present 3 estimates, corresponding to the three spacing scenarios. The method by which the estimates were derived is not currently available. In comparison with our estimates of capacity presented below, the results seem rather high.

Probabilistic Analysis. The following equations can be used to determine maximum capacity, in terms of transponders:

- a) combined capacity of C and Ku band:

$$CAP_{ck} = \left(\frac{72}{S_c} \cdot t_c + \frac{72}{S_k} \cdot t_k \right) p$$

- b) combined capacity of C, Ku, and Ka band:

$$CAP_{cka} = CAP_{ck} + \frac{72}{S_a} \cdot t_a \cdot p$$

where:

- S_c = satellite spacing in C band, in degrees
- S_k = satellite spacing in Ku band, in degrees
- S_a = satellite spacing in Ka band, in degrees
- t_c = average number of transponders per satellite, C band
- t_k = average number of transponders per satellite, Ku band
- t_a = average number of transponders per satellite, Ka band
- 72 = the size of the domestic orbital arc, in degrees
- p = fraction of the 72° designated for use by the U.S.

A probability distribution on capacity can be produced by assigning probability distributions to the variables in the above model. Again we have assigned illustrative distributions, which are shown in Table 10. The data on spacing is based on the scenarios in the ITT report. It will be assumed there is complete probabilistic dependence between S_c , S_k , and S_a . That is, if S_c takes on its low value, S_k and S_a do also. The three variables relating to satellite transponder capacity, t_c , t_k , and t_a , have been taken as certain for this analysis.

From these distributions, cumulative distributions on capacity without and with the Ka band were derived; the results are shown in Figures 5 and 6. Again, it is pointed out these results assume no re-use technologies are applied. The impact of re-use on capacity will be examined in later sections.

4. The Probability of Saturation

In this section we determine the likelihood of system saturation by 1990 if re-use technologies are not employed. To do this, we compare our probability distribution on total demand, from Figure 4, to the distributions on capacity without and with the Ka band, shown in Figures 5 and 6 respectively. We assume probabilistic independence between the sets of variables making up the demand and the capacity models.

Table 10: Probability Distribution for the Capacity Model

<u>Variable</u>	<u>low value</u> <u>(prob. = .25)</u>	<u>nominal value</u> <u>(prob. = .5)</u>	<u>high value</u> <u>(prob. = .25)</u>
s_c	4.5^0	4^0	3^0
s_k	4.5^0	3^0	3^0
s_a	4.5^0	3^0	2^0
t_c	-	24	-
t_k	-	12	-
t_a	-	24	-
p	.33	.50	.75

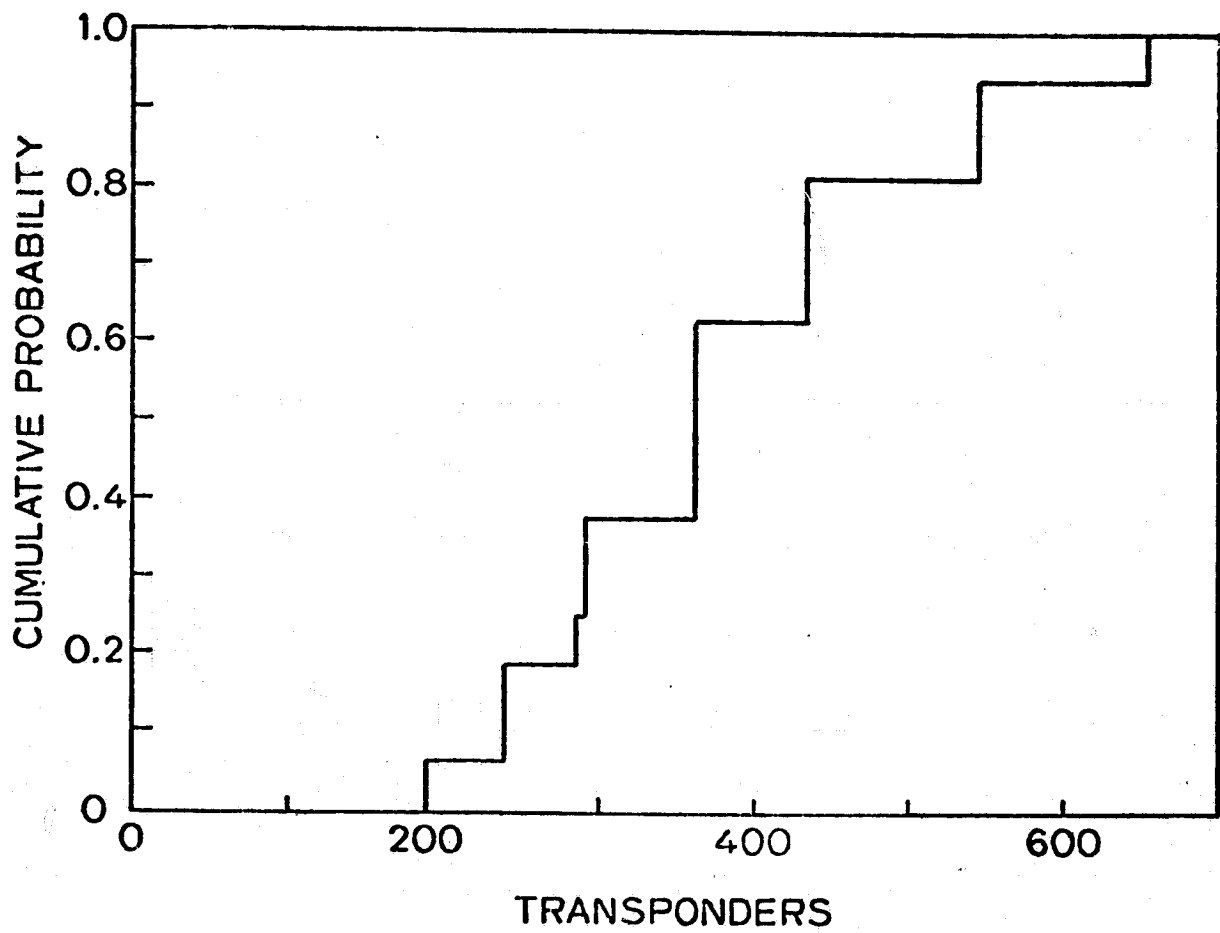


Fig. 5: Distribution on System Capacity without Re-Use and without Ka band

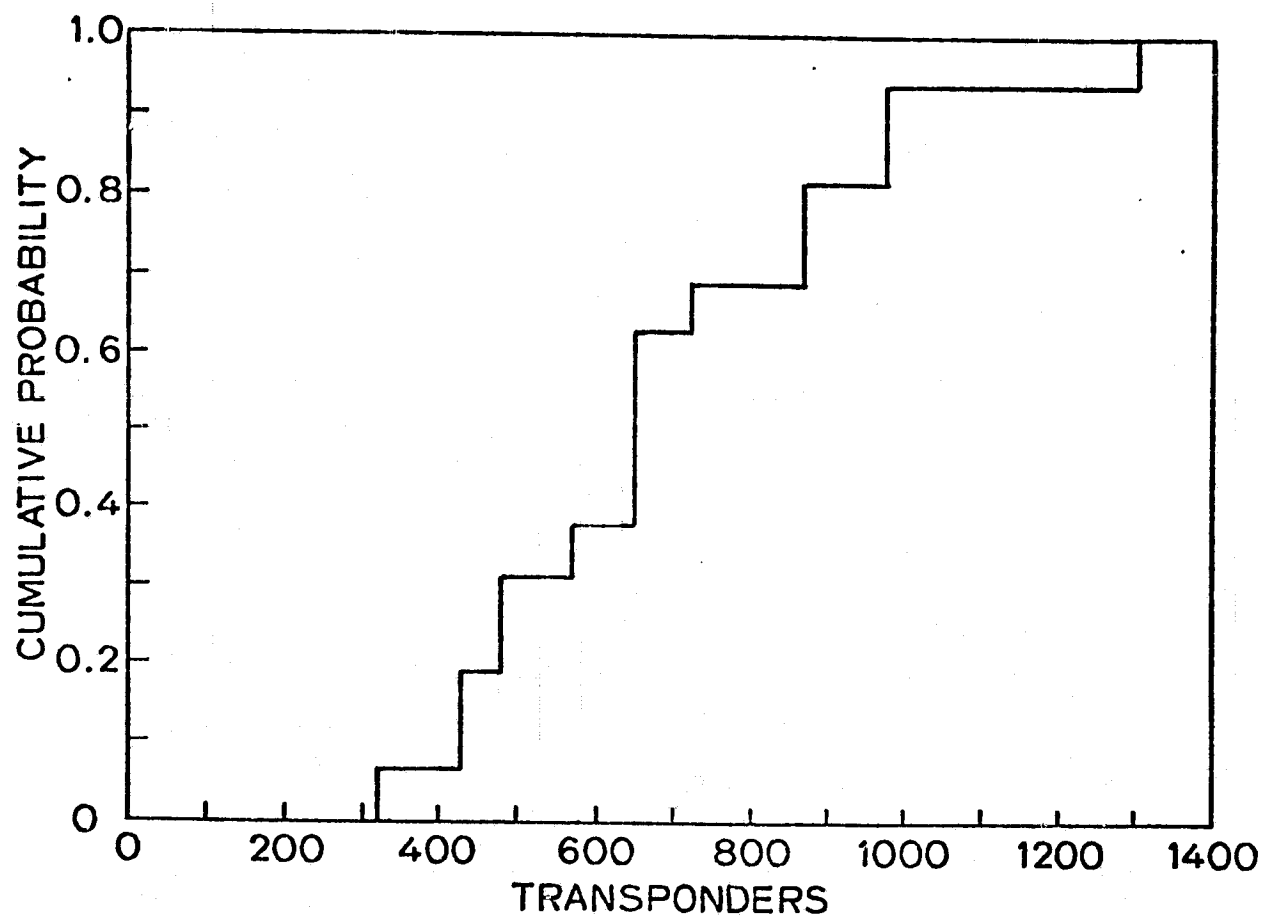


Fig. 6: Distribution on System Capacity without Re-use but with Ka band

We first examine the "most likely" values of the distributions. The median value of demand is 690 transponders; the median capacity without Ka is 360 transponders, and with Ka is 648 transponders. Using the most likely demand and capacity values, we can calculate that without Ka the system can meet only 52% of demand in 1990, while with the Ka band the system can meet 94% of the demand.

Moving away from the "most likely" case, we can use the complete distributions to calculate the overall probability of saturation; i.e., the probability that demand exceeds capacity. The equation used is:

Probability of Saturation =

$$\sum_{q \in Q} \text{Prob} \left(DT > q \mid CAP = q \right) \cdot \text{Prob} \left(CAP = q \right)$$

where Q is the set of all values in the capacity distribution, and DT is the demand for transponders. We have assumed probabilistic independence between demand and capacity.

Therefore:

Probably of Saturation =

$$\sum_{q \in Q} \text{Prob} \left(DT > q \right) \cdot \text{Prob} \left(CAP = q \right)$$

The result of these calculations are:

- without Ka band: .86 probability of saturation
- with Ka band: .54 probability of saturation

Thus without the Ka band and without re-use it is very likely that saturation will occur. Even with the Ka band, the probability of saturation is still greater than .5. This suggests re-use technologies will probably be needed if demand is to be met. In the next section we examine alternative ways of expanding system capacity.

5. Capacity Expansion Alternatives

If demand in 1990 exceeds the capacity of the C and Ku bands (as it appears likely it will), capacity expansion will be required. In this section we discuss how re-use and/or Ka band service might be used to provide additional capacity.

We will avoid consideration of the details of the technological alternatives employed. For example, there are many possible re-use technologies that are or will be available; some of these are coding and modulation techniques, dual polarization, antenna sidelobe suppression, satellite-to-satellite links, and the multiple beam antenna with on-board switching. In the remainder of the paper we assume that one aggregate re-use technology is available. The aggregate technology could include one or more of the above technologies. Presumably the technologies with the lowest marginal costs of use would be selected for use first. The exact configurations of a system would be determined by systems engineering studies. For Ka band service, we ignore attenuation and reliability problems, and assume the service provided is indistinguishable from C and Ku band service.

Analysis of Some Expansion Scenarios. The degree to which expansion will be required depends on the demand level in 1990. From the probability distribution on demand from figure 5 we select three demand scenarios:

- "low" : demand is 415 transponders
- "nominal": " 690 "
- "high" : " 1100 "

In order to keep the analysis simple, we will not use the probability distributions on capacity from Figures 5 and 6. Instead we will take capacity to be certain, and assign the "most likely" values:

- C band: capacity is 216 transponders
- Ku band: " 144 "
- Ka band: " 288 "

Finally, we will consider three technological alternatives, and compare them in terms of their ability to meet demand. They are:

- A. Neither Ka band or re-use are available.
- B. Ka band is available; re-use is not.
- C. Ka band is not available; both the C and Ku bands can be re-used several (3 to 20) times, using an aggregate "package" of technologies.

The alternatives presented are just examples; the list is in no way comprehensive.

The alternatives and the demand scenarios are laid out in tree form in Figure 7. On the right side of the tree the ability of the alternatives to meet each of the three demand levels is described.

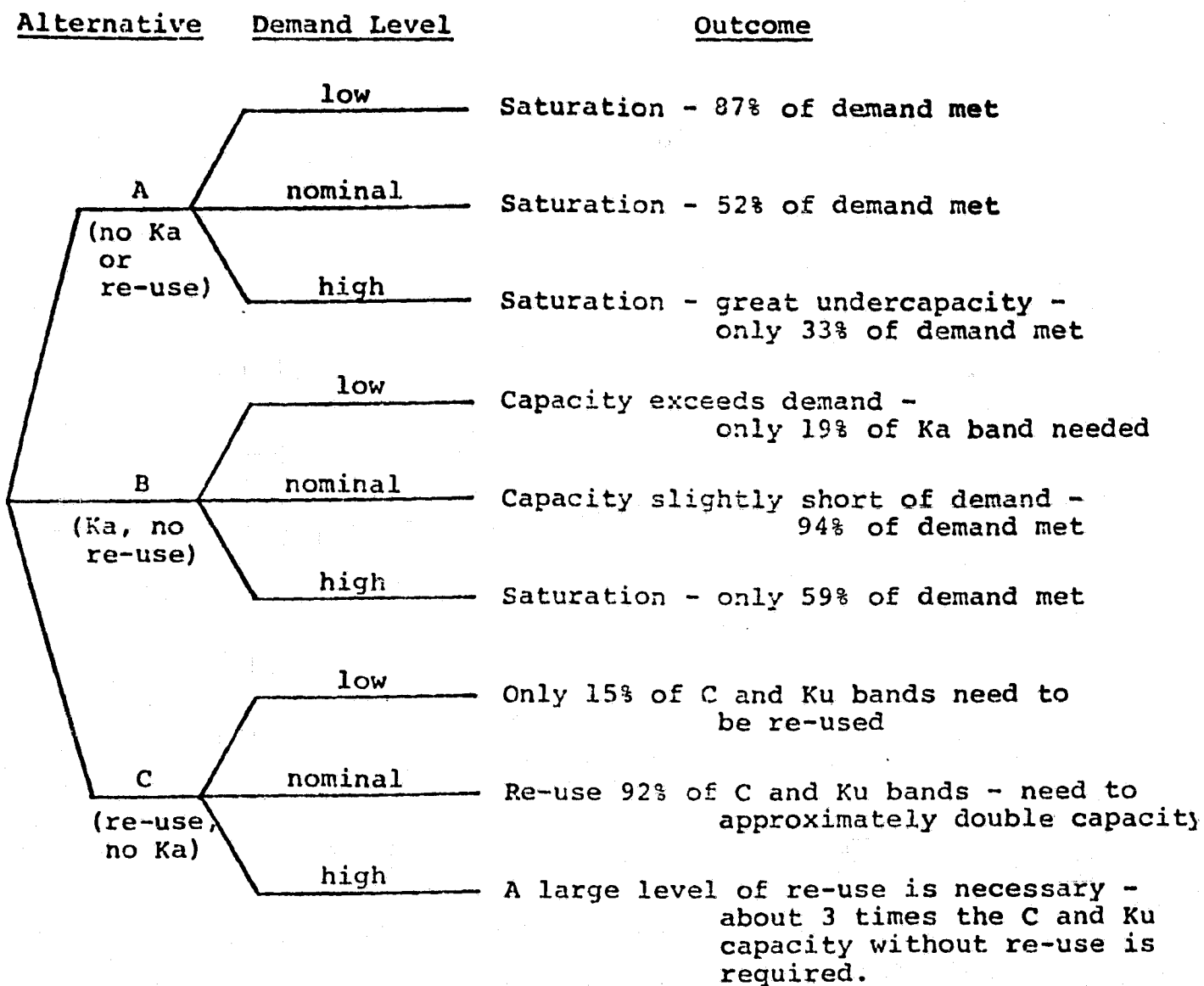


Fig. 7: Scenarios

In Section 4, comparing the full distribution on total demand to the distribution on total capacity led to the conclusion that there is a probability of .86 that demand will exceed capacity if neither re-use or Ka band are available. In the cruder analysis here, we see that in no case can demand be met by just the C and Ku bands without re-use. At the "low" demand level, either a small amount of re-use or a small portion of the Ka band are required to meet demand.

At the nominal demand level, the Ka band on its own falls just short of meeting demand. Under Alternative C, it is necessary to re-use the C and Ku bands so that capacity is approximately doubled. It appears that given a moderate level of success in developing either technology, this level of demand can be met. If a large number of re-use technologies were to become available between now and 1990, there is the potential for a large amount of overcapacity.

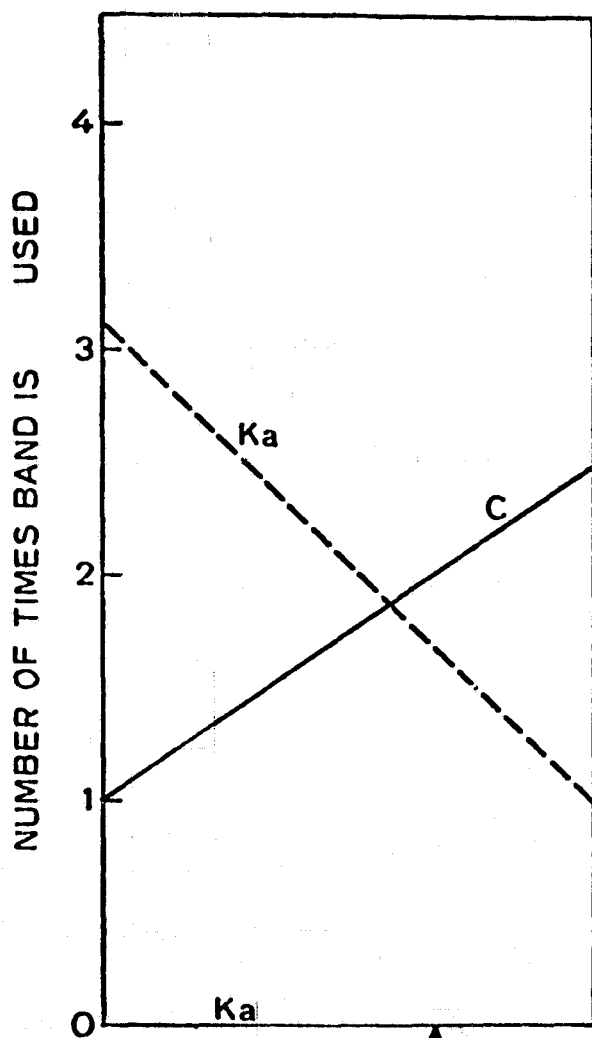
At the high demand level, the addition of the Ka band alone does not come close to meeting demand. Under Alternative C, the C and Ku bands must each be expanded to triple their base capacity in order to meet demand. Therefore unless Ka band and/or re-use are successfully developed by 1990, a large gap between demand and supply could result if the demand level is high.

Combining Ka Band and Re-use Technologies. In general, there are many combinations of C band re-use, Ku band re-use, and Ka service that can be used to meet demand. Examples of combinations that could be used to meet the nominal demand level of 690 transponders are shown in Figure 8. The graph on the left of Figure 8 shows possible combinations if the Ka band is not available; the graph on the right assumes Ka band is available (but cannot be re-used). A vertical line drawn at any point on a graph shows how demand is met: the amount that C band is expanded over its capacity without re-use, the amount that Ku band is expanded over its capacity, and whether or not the Ka band is used.

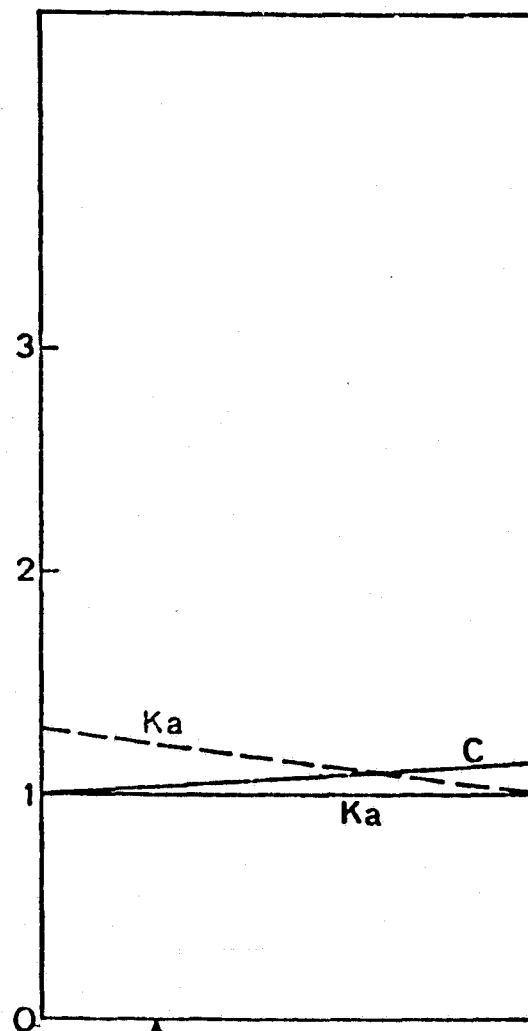
If the demand for satellite services is taken as insensitive to price, then the optimal choice of satellite technologies corresponds to the problem of finding the system configuration that meets demand at least cost. In the next section we introduce cost data into the analysis.

6. Analysis of the Comparative Costs of Alternatives

By quantifying the uncertainties relating to cost, we can expand the decision analysis framework of the earlier sections of the paper. Unfortunately, the cost data available so far, from the contractor reports and from other sources, is sketchy. Below we present a general outline of how the analysis should proceed. We then present an example of a cost comparison between competing technologies, using illustrative cost data.



a) without Ka band



b) with Ka band

Fig. 8: Possible Combinations of C band Re-use, Ku band Re-use, and Ka band to Meet a Demand of 690 Transponders

The General Framework. Figure 9 shows a decision tree, in generic form, that determines the expected cost of meeting demand for a given technological alternative. For example, an alternative might be the use of the Ka band, or the introduction of some combination of re-use technologies. There are four state variables represented in the tree. The first two variables are total demand, and system capacity without re-use for each band. Comparison of the values taken on by these variables determines to what extent frequency expansion is needed. The last two variables are the technical performance of the alternative at the level of service required to meet demand (e.g., amount of re-use attainable), and the resulting cost. In some cases the value of one or both of these variables may be relatively certain. The last two variables provide a general representation; they would appear in different forms for specific analyses. The values at the right side of the tree determine the cost of meeting the resulting demand level. In some cases it may not be possible to meet some high levels of demand with the given technological alternative. "Rolling back" the tree determines the expected cost of using the alternatives.

The cost of terrestrial technologies in direct competition with satellites will also determine the desirability of using the various satellite technologies. The effect of competition from terrestrial service will show up in the satellite capture ratio in the demand model. Since we have even less data on projected terrestrial costs than on satellite

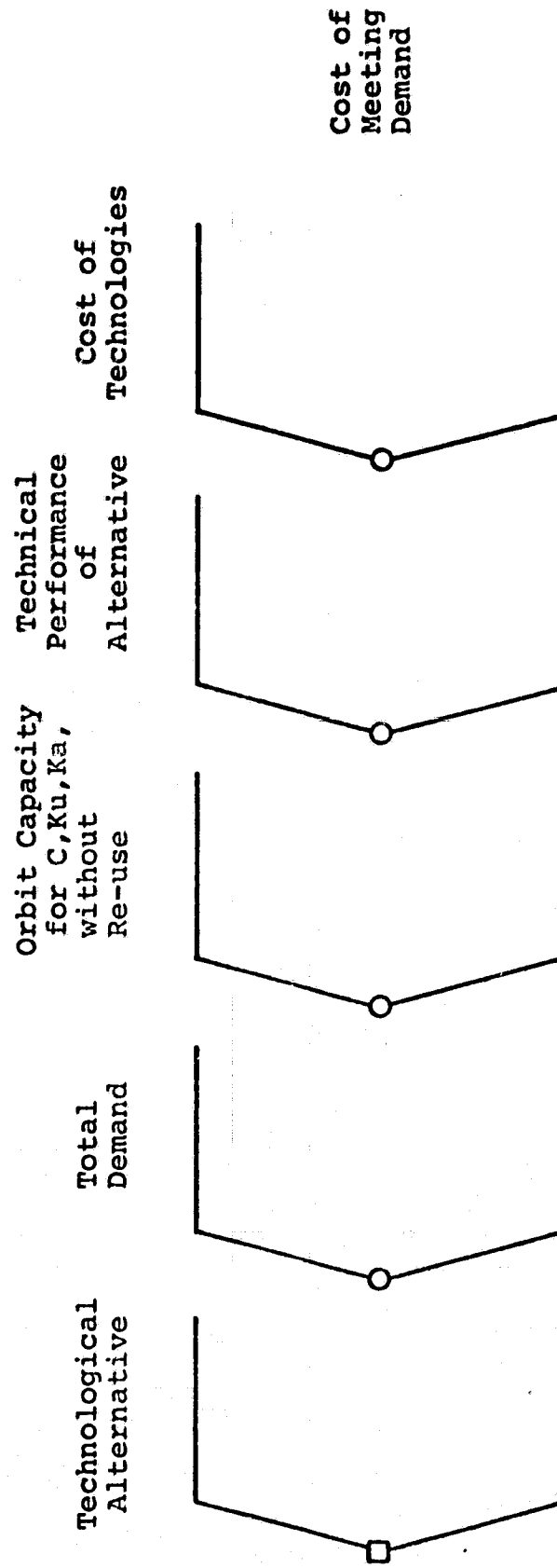


Fig. 9: Tree for Evaluating Competing Technologies

costs, we will assume the contractors' estimates of satellite capture ratios included the possibility of new or improved terrestrial technologies. As noted in Section I, it would be desirable in the future to formulate a structural model that approached the question of terrestrial/satellite tradeoffs in a more comprehensive manner. Pricing policies should certainly be included, as should latent demand--demand not currently observable, but which might appear if the costs were reduced substantially.

An Illustrative Cost Comparison of Ka Service to C Band Re-use in 1990. The following analysis uses illustrative cost data. Its purpose is to show how uncertainty about cost enters into the analysis. A full description of an expanded form of the example appears in Appendix C.

We compare two technological alternatives. The alternatives are simply examples; many other possibilities exist. The alternatives are:

1. C-band re-use. The C band spectrum is re-used through a variety of technologies. The Ku band is used before re-use is employed on the C band. The Ka band cannot be used. For the sake of computational ease, we assume no re-use technologies are used for the Ku band.⁴
2. Ka band. The Ka band can be used. No re-use is possible for the C band or the Ku band. In performing the analysis it was found that the capacity

available from the use of all three bands often fell short of meeting demand. Therefore re-use of the Ka band only is allowed, say through the use of spot beams with on-board switching.⁵

The decision tree for the analysis is shown in Figure 10. There are four state variables: total demand, system capacity, cost of C-band re-use, and Ka system cost.

The total demand distribution from Figure 4 was approximated by a three-branch distribution. In order to reduce the amount of analytic effort required, we again use deterministic values for system capacity. The values used are:

$$\text{C band: } CAP_c = 216$$

$$\text{Ku band: } CAP_k = 144$$

$$\text{Ka band: } CAP_a = 288$$

Uncertainty on system capacity could be added to the analysis with no change in the methodology used.

The basic unit of cost used is dollars per transponder. We are interested only in relative costs. It is assumed the costs for the C and Ku bands are certain, while Ka band cost is uncertain. The following data are used:

$$Q_c = \text{cost/transponder in C-band} = \$1$$

$$Q_k = \text{cost/transponder in Ku-band} = \$1.50$$

$$Q_a = \text{cost/transponder in Ka-band is described by the distribution:}$$

$$\text{Prob} \left(Q_a = \$1.50 \right) = .5$$

$$\text{Prob} \left(Q_a = \$5.00 \right) = .5$$

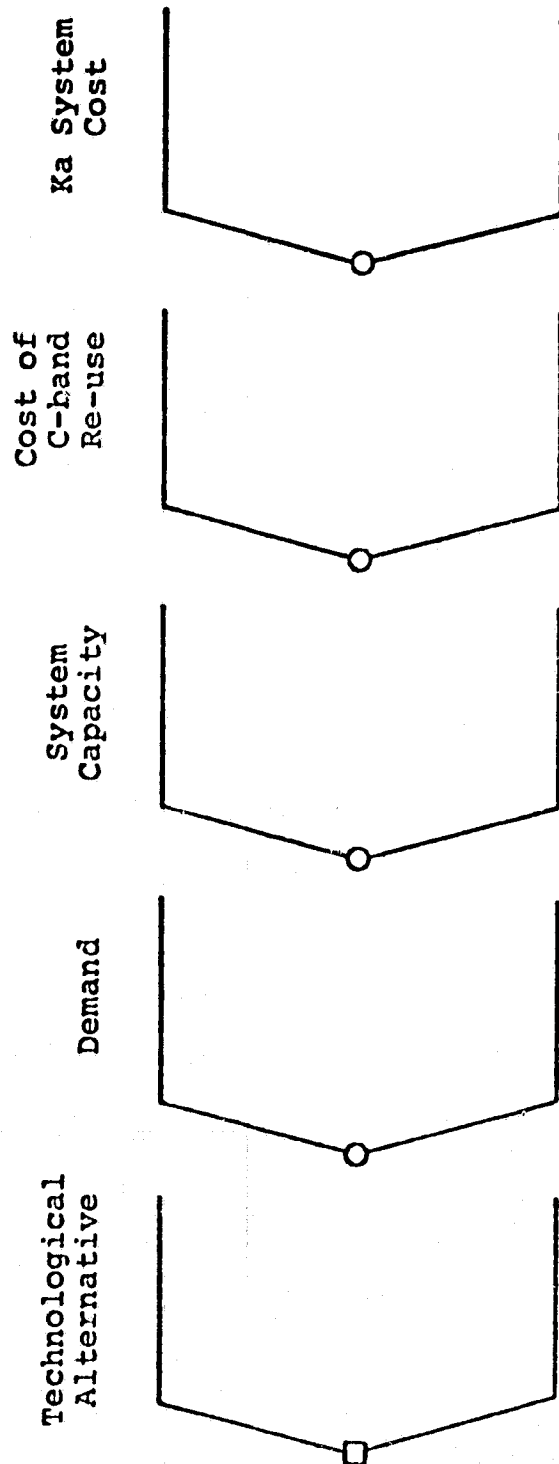


Fig. 10: Tree for C band Re-use vs. Ka band Comparison

A simple model of re-use cost is employed for C band re-use (and for Ka band re-use when required). It is assumed re-use technologies are added one at a time until demand is met. Each technology allows the entire spectrum capacity to be re-used; i.e., it doubles capacity. Cost increases for each re-use, as follows:

$$CRU(n) = Qm^n \quad (2)$$

where:

$CRU(n)$ = marginal cost per equivalent transponder when the spectrum is being used for the n th time

Q = cost per transponder without re-use

m = a multiplier ($m > 1$)

n = number of times the spectrum is being re-used

This model is used for illustrative purposes. Its form does seem plausible. The acquisition of data on re-use costs would allow this and alternative model forms to be tested with data and compared in terms of suitability.

For Alternative 1, C-band re-use, the multiplier is m_c , and is uncertain:

$$\begin{aligned} \text{Prob} \left(m_c = 1.2 \right) &= .5 \\ \text{Prob} \left(m_c = 2 \right) &= .5 \end{aligned}$$

For cases where re-use is required for the Ka band, the multiplier m_a is taken to have the value of 1.2.

Figure 11 shows the full decision tree, with the deterministic capacity variable removed. At the right side of each final node in the tree is the resulting minimum cost for meeting demand. The cost calculations are described in Appendix C.

The tree can be rolled back to yield an expected cost of meeting demand for each alternative. The results are:

Alternative 1, (C-band re-use):
Expected cost = \$1621

Alternative 2, (Ka band):
Expected cost = \$1802

Because the data used here is illustrative, no definitive statements can be made from the results. However, we can see how the data could be used for decision-making purposes. If Research Programs 1 and 2 were available that led respectively to Alternatives 1 and 2 being available in 1990, then it appears that Program 1 leads to a savings of \$181 compared to Program 2. The steps involved in extending the analysis to give explicit consideration to R&D alternatives are discussed in the next section.

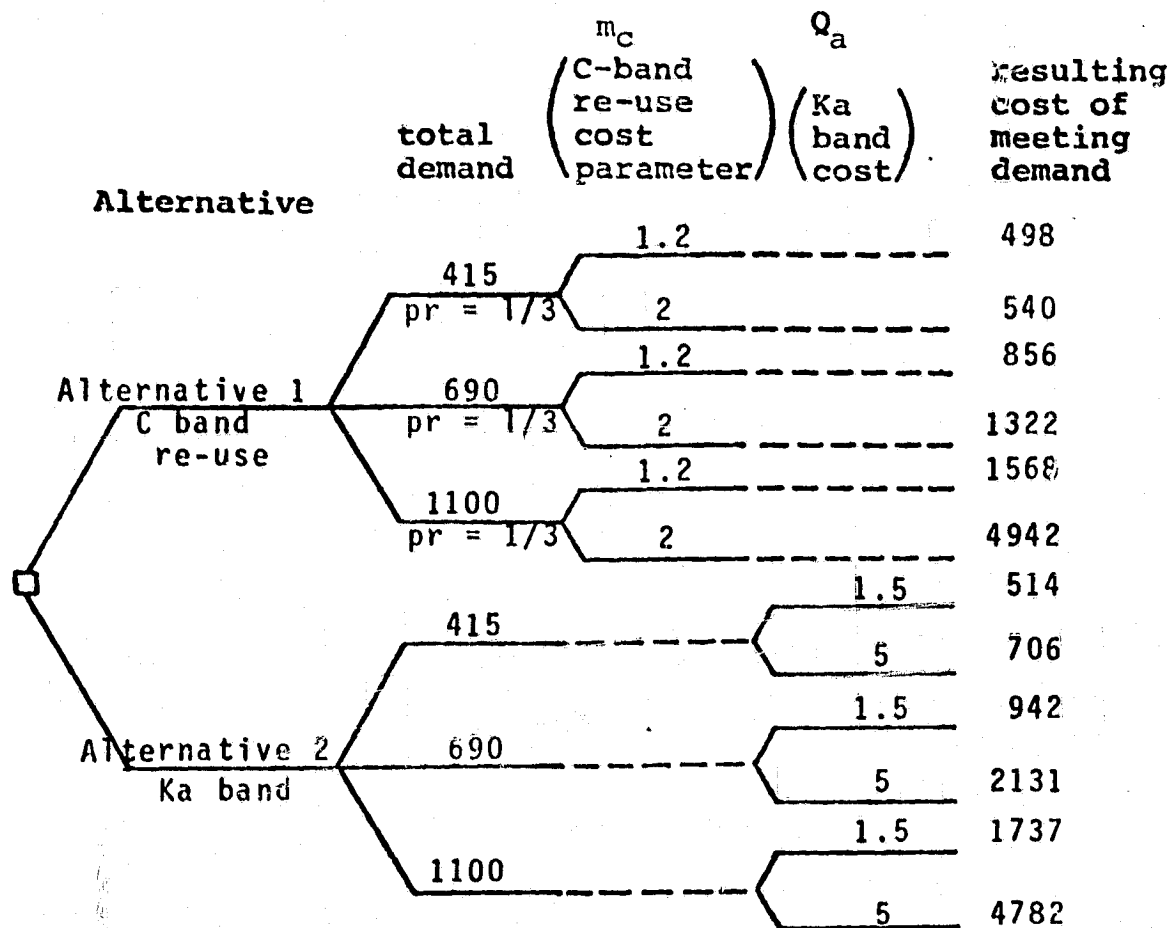


Fig. 11: Decision Tree for Cost Comparison

Section III

APPLICATION OF THE APPROACH TO COMMUNICATIONS SATELLITE R&D DECISIONS

NASA faces a range of decisions in the area of communications satellite policy. The analysis presented here is focused primarily on the choice between Ka band technologies and re-use and conservation alternatives. The discussion here illustrated how a decision analysis approach can be used to address that question.

The analysis, however, intentionally leaves out many issues in order to illustrate analytical techniques. The full approach as outlined in Section I requires consideration of many other issues and much more attention to data, involvement of knowledgeable experts and decision makers, and structural modeling of satellite supply and demand. In addition, to be useful to NASA R&D planning, the focus of an analysis would have to be on the R&D allocation decisions that precede the technology deployment decisions.

Figure 12 illustrates the structure of an R&D decision analysis. This figure shows a two-stage decision tree for the R&D decision problem. In the first stage, R&D allocation decisions and R&D outcomes are represented. In the second stage the deployment decisions and outcomes are represented. The analysis of the second deployment stage would be similar to the analysis presented in the preceding section.

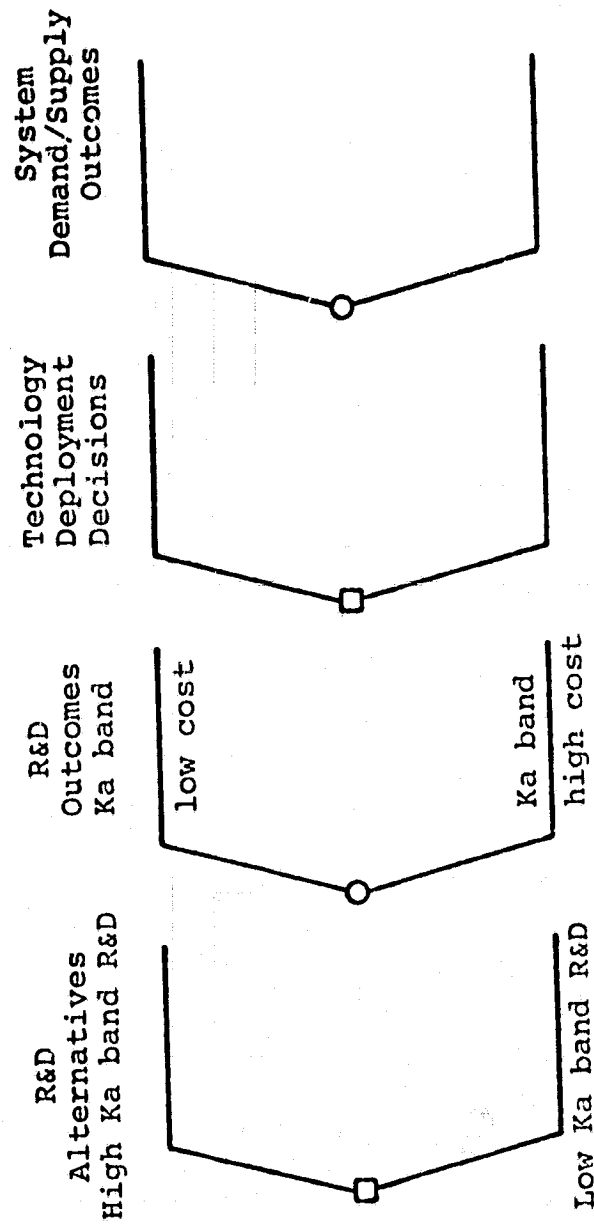


Fig. 12: Two-Stage Decision Tree for R&D Analysis

The analysis of the R&D stage would use the same decision analysis techniques as illustrated in the preceding section. The additional information requirements would include information on the cost of each R&D alternative and the probabilities of various outcomes of the R&D.

Within this structure alternative NASA R&D programs can be represented as alternatives. The value of an R&D program would be characterized in terms of the change in information produced by the program including delineation of new technical alternatives. Numerical values for this information could be imputed from the resulting changes in deployment decisions and reduced costs or increased level of communications services.

We have not carried out the detailed R&D analysis in this paper. Such an analysis should properly be carried out with the close involvement of the relevant technical specialists and NASA officials. This two-stage R&D decision analysis structure when combined with appropriate structural models of communications markets would provide significant insights to NASA R&D planning and could serve as a basis for a rational allocation of NASA communications satellite R&D funds.

Notes

1. Calio, Anthony J. Statement before the Subcommittee on Space Sciences and Applications, Committee on Science and Technology, U.S. House of Representatives, Feb. 20, 1979.
2. For a general introduction to decision analysis, see: Howard, R. A., "Decision Analysis: Applied Decision Theory," North, D. W., "A Tutorial Introduction to Decision Analysis," Howard, R.A., "The Foundations of Decision Analysis," all reprinted in Readings in Decision Analysis, SRI International, 2nd ed., 1977.
3. See: Spetzler, C. S., and C. S. Stael von Holstein, "Probability Encoding in Decision Analysis," reprinted in Readings in Decision Analysis, SRI International, 2nd ed., 1977.
4. It may in fact be easier to re-use Ku band than C band, suggesting the alternative of re-using Ku but not C might be more realistic than the one presented here.
5. Re-use of the Ka band will likely use Ku band re-use technology, and therefore should be feasible.

APPENDIX A. Western Union Demand Data and
Comparison to the ITT Data

Below we summarize the demand data from the Western Union (WU) report and, where possible, compare it to the ITT data. Western Union's demand model appears to be comprehensive, and fairly complex. It builds up a forecast by aggregating data on a large number of telecommunications services.

Table A-1 shows Western Union's forecast of net long haul traffic for voice, data and video services for 1980, 1990, and 2000. A terrestrial/satellite cost model is then used to split out satellite traffic from the total long haul traffic. The estimate of satellite traffic appears in Table A-2.

The data for the three types of services in the above tables are each stated in different units. This makes comparisons between service types and with the ITT data difficult. The data is eventually all converted into a common unit, equivalent transponders. The process used to make the conversions is not known at this point. There is some indication it is a relatively complex process, and includes consideration of peak hour demand, among other factors.

Western Union's resulting estimates of total long haul traffic and satellite traffic in transponders are shown in Tables A-3 and A-4. In each case we have shown the demand is split between the three types of service. From these data,

Table A-1: WU - Forecast of Annual Long Haul Traffic

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice (1/2 circuits)	2,100,000	5,300,000	13,700,000
Data (terabits/year)	1,100	7,000	27,600
Video (wideband channels)	170	290	450

Table A-2: WU - Forecast of Satellite Demand

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice (1/2 circuits)	345,000	892,000	2,905,000
Data (terabits/year)	464	3,215	14,533
Video (wideband channels)	79	187	340

Table A-3: WU - Total Long Haul Traffic in Transponders

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	2100 (92%)	3407 (91%)	8828 (93%)
Data	13 (1%)	75 (2%)	320 (3%)
<u>Video</u>	<u>176 (7%)</u>	<u>253 (7%)</u>	<u>357 (4%)</u>
Total	2289 (100%)	3735 (100%)	9505 (100%)

Table A-4: WU - Satellite Demand in Transponders

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	346 (80%)	360 (76%)	1862 (80%)
Data	61 (1%)	42 (5%)	201 (9%)
<u>Video</u>	<u>80 (19%)</u>	<u>157 (19%)</u>	<u>258 (11%)</u>
Total	432 (100%)	829 (100%)	2321 (100%)

Table A-5: WU - Satellite Capture Ratio (derived) in percent

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	16	18	21
Data	46	56	63
Video	45	62	72

we are able to derive a satellite capture ratio, which is shown in Table A-5.

It is interesting to compare data from the latter three tables to the ITT data presented in Section 2. In order to facilitate comparison, the relevant pieces of data will be reproduced side-by-side.

Table A-6 compares the contractors' estimates of the way total long haul traffic is split between the three types of service. There is a major discrepancy over the importance of data traffic. Although the difference could be attributable to differing perceptions of what is going to happen with respect to the various technologies, it is also possible the discrepancy stems from the use of different accounting conventions. The fact that the results are so different for 1980, essentially the present, supports the latter view. The discrepancy will hopefully be resolved when the full reports become available.

In Table A-7 the estimates of satellite capture ratio are presented. The results are again very different in 1980, but concur to a large degree in 1990 and 2000.

The estimates of satellite demand in transponders is presented in Table A-8. The forecasts presented in Table A-8 are the product of the full analysis of each of the contractors, and are therefore the most interesting data for comparison. As can be observed, the forecasts are so different that one questions whether they are based on the same set of basic

Table A-6: ITT and WU - Comparison of Split of Total
Long Haul Traffic Between Service Types - in percent

Format: (ITT data, WU data)

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	(74, 92)	(76, 91)	(77, 93)
Data	(15, 1)	(15, 2)	(12, 3)
Video	(11, 7)	(9, 7)	(11, 4)

Table A-7: ITT and WU - Satellite Capture Ratio - in percent

Format: (ITT data, WU data)

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	(2, 16)	(15, 18)	(25, 21)
Data	(1, 46)	(50, 56)	(60, 63)
Video	(50, 45)	(60, 62)	(60, 72)

assumptions and definitions. Although it is a major task to critique either of the analyses and to improve them, one apparent assumption of the WU analysis is that transponder capacity remains constant at 50 MSPS. If the WU results are recalculated with the increasing transponder capacities used by ITT, the forecast for the total number of transponders, as shown in Table A-9, is much closer to ITT's. This does not mean one analysis is correct and the other is not, but at least it offers one explanation for the discrepancies. We note that there is still a major divergence in terms of the split between voice, data and video traffic.

Table A-8: ITT and WU - Demand for Transponders

Format: (ITT data, WU data)

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	(21, 346)	(225, 630)	(474, 1862)
Data	(5, 6)	(345, 42)	(436, 201)
<u>Video</u>	<u>(35, 80)</u>	<u>(110, 157)</u>	<u>(211, 258)</u>
Total	(61, 432)	(690, 829)	(1121, 2321)

Table A-9: WU - Demand for Transponders, modified to include increasing transponder capacity (in 36 MHz equivalent transponders)

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Voice	412	438	862
Data	7	29	93
<u>Video</u>	<u>95</u>	<u>109</u>	<u>119</u>
Total	514	576	1074

APPENDIX B. The Probability Distributions for Demand
for Voice, Data, and Video Services

The distributions are shown on the next three pages.

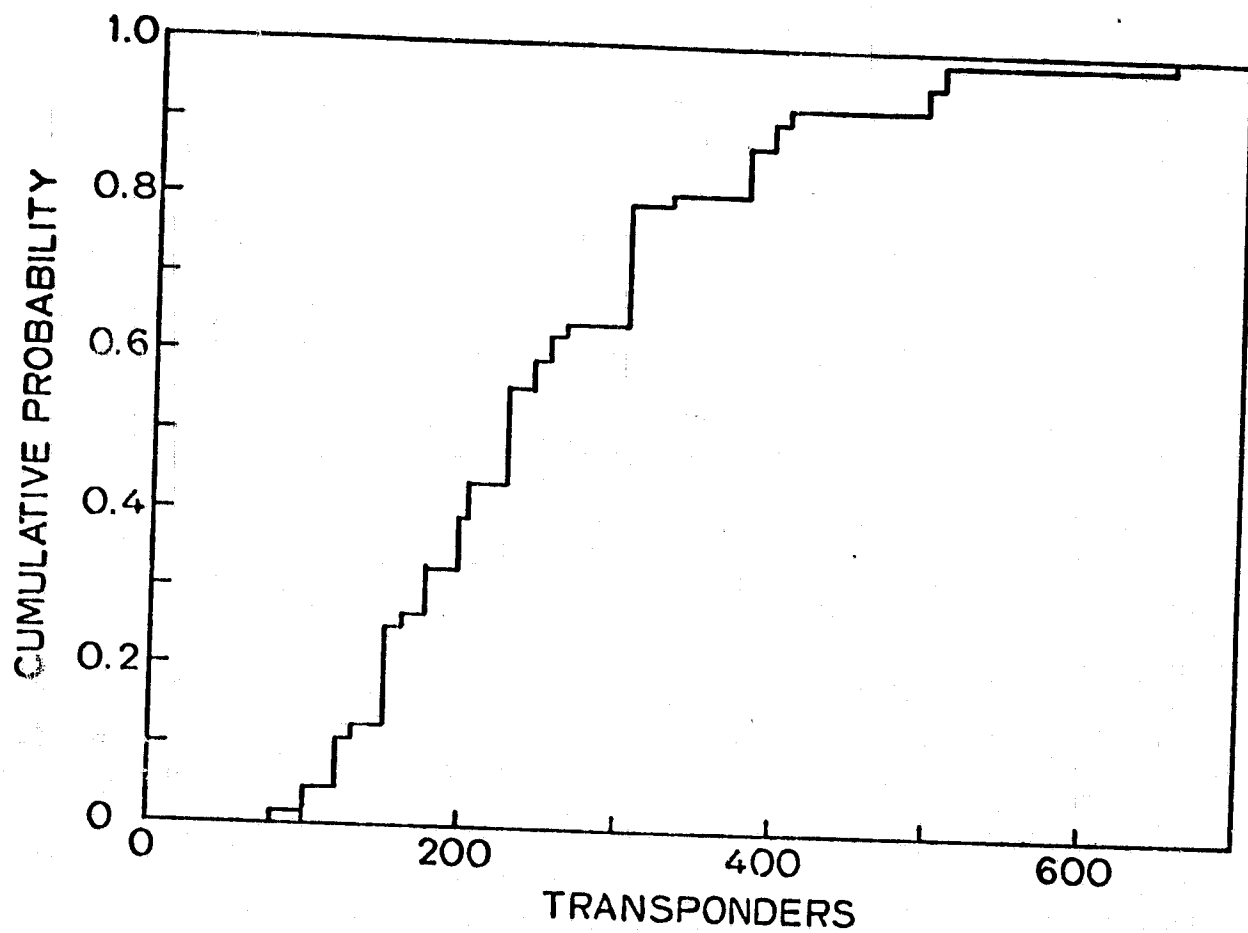


Fig. B-1: Cumulative Distribution on Voice Demand for Transponders

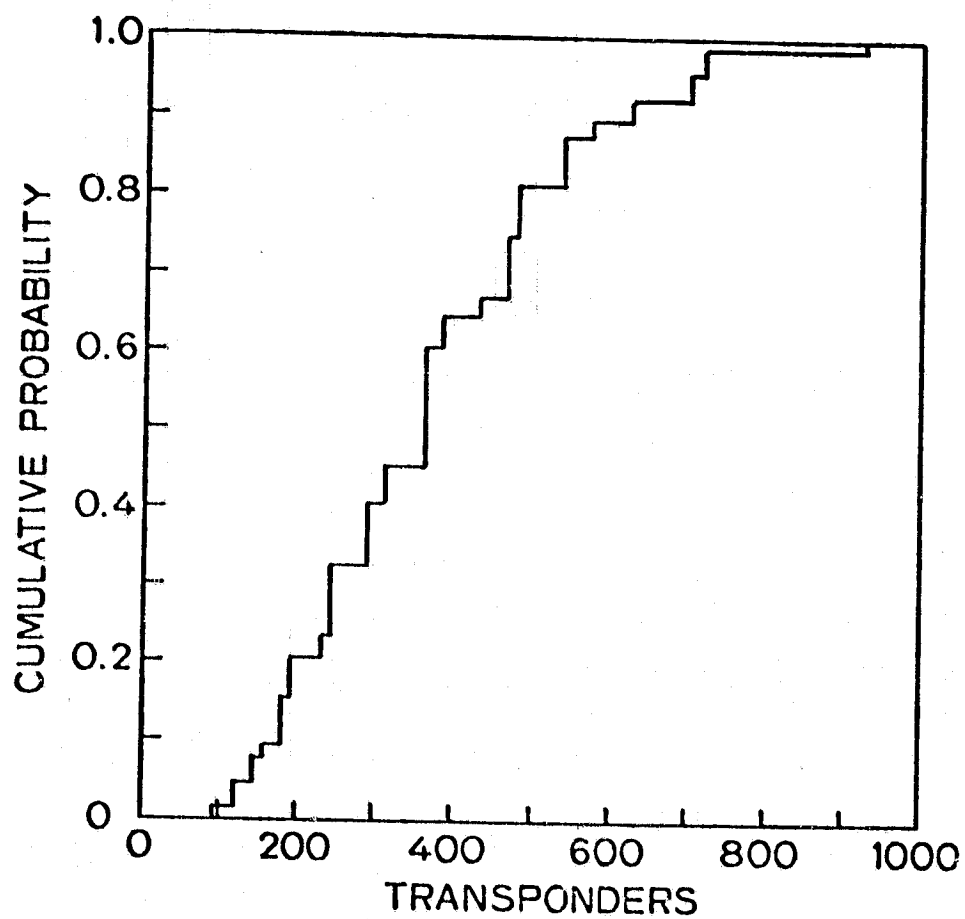


Fig. B-2: Cumulative Distribution on Data Demand for Transponders

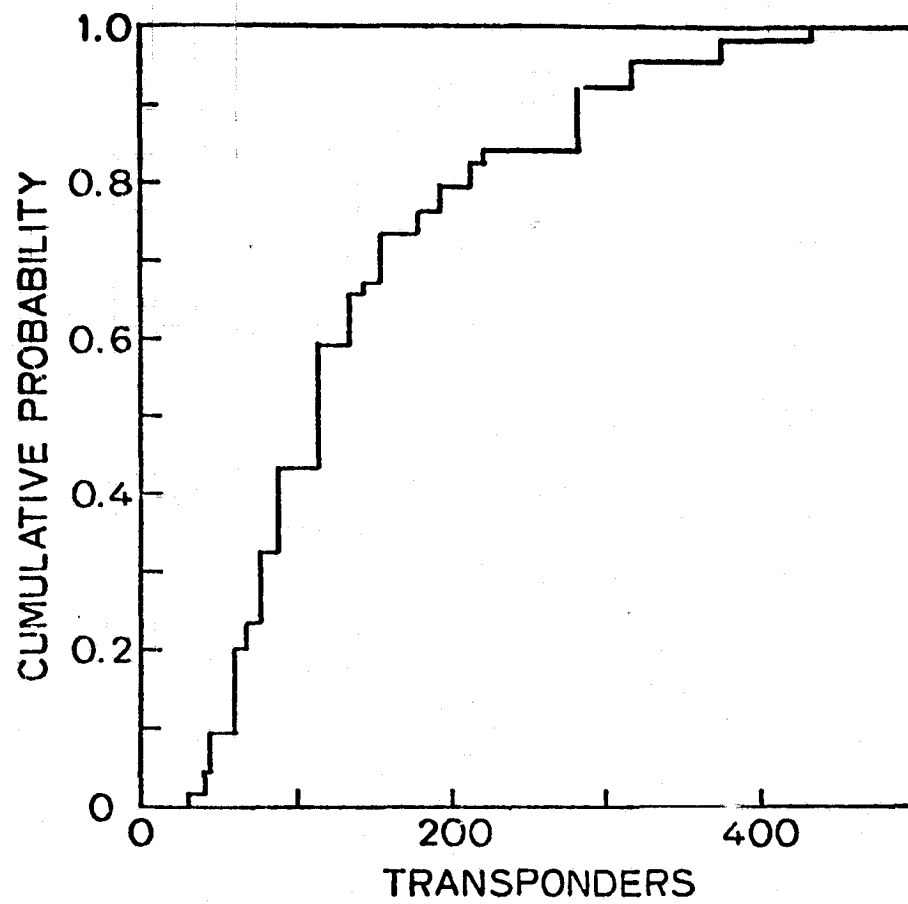


Fig. B-3: Cumulative Distribution on Video Demand for Transponders

APPENDIX C. Expanded Version of the Illustrative Cost Comparison

In Section 6 we presented an illustrative analysis of the costs of Ka band service and C band re-use. This appendix is an expanded version of that analysis: a third technological alternative has been added. A full description of the cost calculations is also presented.

We compare three technological alternatives.

1. C-band re-use. The C band spectrum is re-used through a variety of technologies. The Ku band is used before re-use is employed on the C band. No re-use technologies are available for Ku band. The Ka band cannot be used.
2. Ka band. The Ka band can be used. No re-use is possible for the C band or the Ku band. In performing the analysis it was found that the capacity available from the use of all three bands often fell short of meeting demand. Therefore re-use of the Ka band only is allowed, say through the use of spot beams with on-board switching.
3. Combination. Both of the above are available. The minimum cost combination for each demand level will be used.

The decision tree for the analysis is shown in Figure C-1. There are four state variables: total demand, system capacity, cost of C-band re-use, and Ka system cost.

The total demand distribution from Figure 4 was approximated by three-branch distribution. In order to reduce the amount of analytic effort required, we again use deterministic values for system capacity. The values used are:

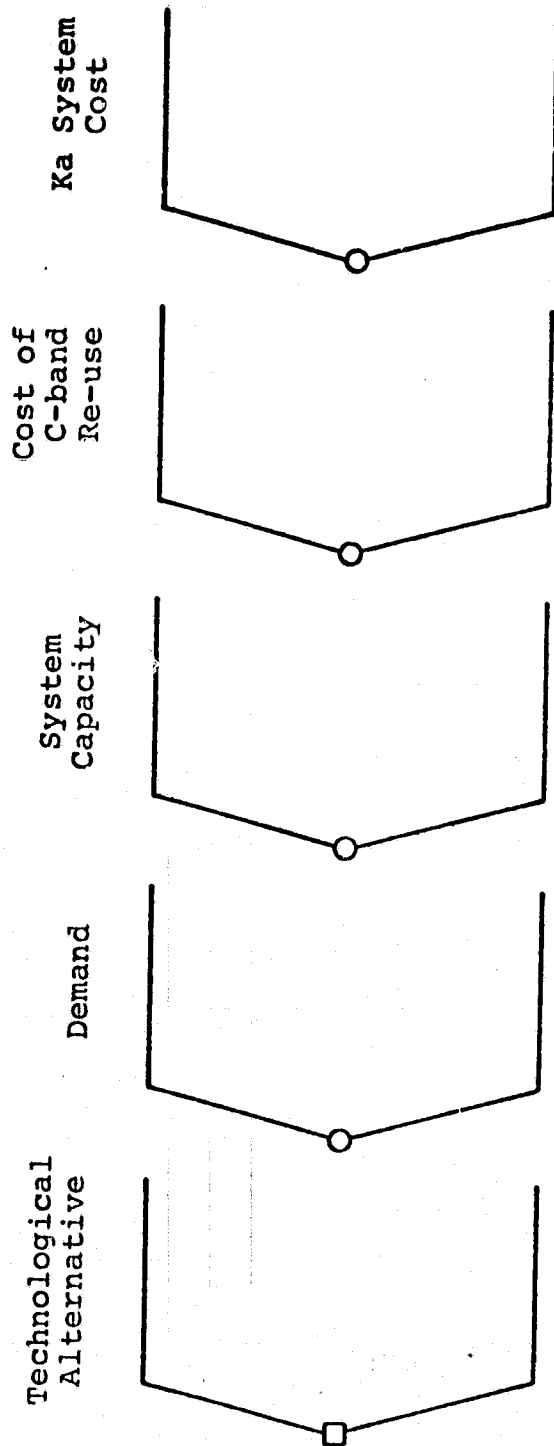


Fig. C-1: Tree for C band Re-use vs. Ka band Comparison

$$\text{C band: } CAP_c = 216$$

$$\text{Ku band: } CAP_k = 144$$

$$\text{Ka band: } CAP_a = 288$$

Uncertainty on system capacity could be added to the analysis with no change in the methodology used.

The basic unit of cost used is dollars per transponder. We are interested only in relative costs. It is assumed the costs for the C and Ku bands are certain, while Ka band cost is uncertain. The following data is used:

$$Q_c = \text{cost/transponder in C-band} = \$1$$

$$Q_k = \text{cost/transponder in Ku-band} = \$1.50$$

$$Q_a = \text{cost/transponder in Ka-band is described by the distribution:}$$

$$\text{Prob} \left(Q_a = \$1.50 \right) = .5$$

$$\text{Prob} \left(Q_a = \$5.00 \right) = .5$$

A simple model of re-use cost is employed for C band re-use (and for Ka band re-use when required). It is assumed re-use technologies are added one at a time until demand is met. Each technology allows the entire spectrum capacity to be re-used; i.e. it doubles capacity. Cost increases for each re-use, as follows:

$$CRU(n) = Qm^n \quad (2)$$

where:

$CRU(n)$ = marginal cost per equivalent transponder when the spectrum is being used for the n th time

Q = cost per transponder without re-use

m = a multiplier ($m > 1$)

n = number of times the spectrum is being re-used

For Alternative 1, C-band re-use, the multiplier is m_c , and is uncertain:

$$\begin{aligned} \text{Prob} \left(m_c = 1.2 \right) &= .5 \\ \text{Prob} \left(m_c = 2 \right) &= .5 \end{aligned}$$

For cases where re-use is required for the Ka band, the multiplier m_a is taken to have the value 1.2.

Figure C-2 shows the full decision tree, with the deterministic capacity variable removed. At the right side of each final node in the tree is a resulting minimum cost for meeting demand. The cost calculations are outlined below.

Cost Calculations - Alternative 1

Demand is met by first using C band, then the Ku band, and then by re-using the C-band as many times (or fraction of a time) as required. For the range of demand values encountered here, the following equation can be used.

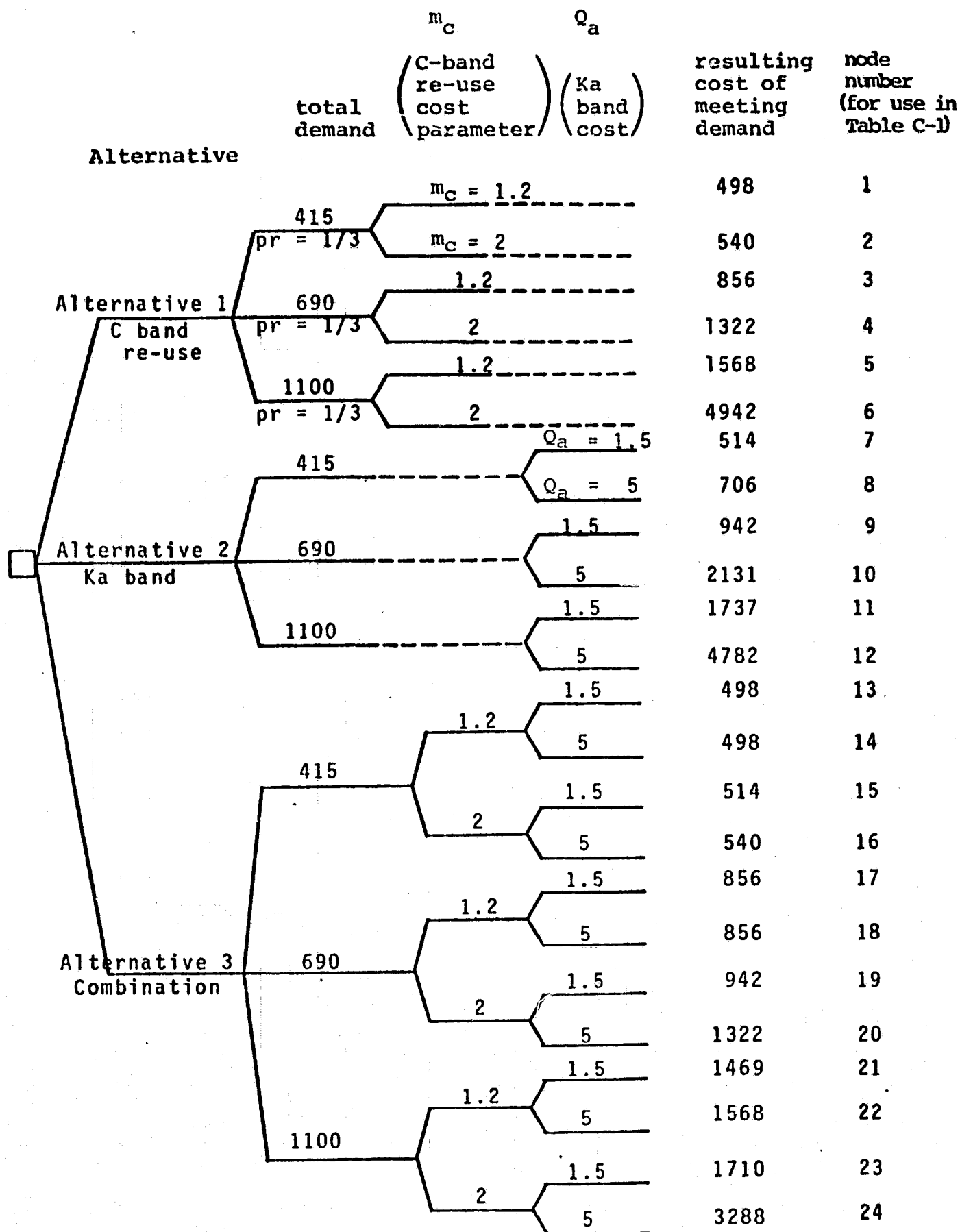


Fig. C-2: Full Decision Tree

Let:

$$R = \frac{DT - CAP_k}{CAP_c}, \text{ where } DT \text{ is demand}$$

INT = largest integer less than R

$$f = R - INT$$

Then the total cost is given by:

$$COST = Q_c \cdot CAP_c \left[\sum_{i=0}^{INT-1} m_c^i + f m_c^{INT} \right] + Q_k \cdot CAP_k$$

The amount of re-use required to meet demand for each demand level is described in Table C-1. The resulting costs are shown on the right side of the tree in Figure C-2.

Cost Calculation - Alternative 2

Demand is met by first using the C, then the Ku, and then the Ka band, and then by re-using the Ka band if necessary. For the range of demand values encountered here, we use the following to calculate cost.

Let:

$$R = \frac{DT - CAP_c - CAP_k}{CAP_a}, \text{ where } DT \text{ is demand}$$

INT = largest integer less than R

$$f = R - INT$$

Total cost is:

Table C-1: How Demand is Met

<u>Alternative</u>	<u>Node Number from Figure 11</u>	<u>Technologies Used*</u>
1	1	Use 19% of Ka band
	2	Use 19% of Ka band
	3	Use Ka band, then re-use 15% of it
	4	Use Ka band, then re-use 15% of it
	5	Use Ka band, then re-use it once, then re-use 57% of it
	6	Use Ka band, then re-use it once, then re-use 57% of it
2	7	Re-use 25% of C band
	8	Re-use 25% of C band
	9	Re-use C band, then re-use 53% of it
	10	Re-use C band, then re-use 53% of it
	11	Re-use C band three times, then re-use 43% of it
	12	Re-use C band three times, then re-use 43% pf it
3	13	Re-use 25% of C band
	14	Re-use 25% of C band
	15	Use 19% of Ka band
	16	Re-use 25% of C band
	17	Re-use C band, then re-use 53% of it
	18	Re-use C band, then re-use 53% of it
	19	Use Ka band, then re-use 15% of it
	20	Re-use C band, then re-use 53% of it
	21	Re-use C band twice, then use Ka, then re-use 9 % of C
	22	Re-use C three times, then re-use 43% of it
	23	Use Ka, re-use Ka, re-use 76% of C band
	24	Re-use C twice, use Ka, re-use 7% of Ka

*C band and Ku band are always used once before C band re-use or Ka band use.

$$\text{COST} = \text{CAP}_a \left[\sum_{i=0}^{\text{INT}-1} m_k^i + f m_k^{\text{int}} \right] + Q_c \cdot \text{CAP}_c + Q_k \cdot \text{CAP}_k$$

The amount of Ka band use required to meet demand for each demand level is shown in Table C-1. The resulting cost values appear in Figure C-2.

Cost Calculations - Alternative 3

Under Alternative 3, it is assumed demand is first met by using the C and Ku bands once. Additional capacity is added through re-use of the C-band and/or through the use and subsequent re-use of the Ka band. Capacity is added in increasing order of its marginal cost. This generates a supply curve for capacity. Table C-2a shows the increase in marginal cost as the C band is re-used, and as the Ka band is used and subsequently re-used. When the appropriate cost parameters are "plugged in," the supply curve is derived by combining the lists for the two technologies and selecting alternatives in order of increasing marginal cost. Since there are two possible values of Ka system cost and two possible values of C band re-use cost, a total of 4 supply curves were needed in order to calculate the costs at the end of the tree. The development of the supply curve for one set of parameters is shown in Table C-2b the resulting supply curve appears in Figure C-3. For a given demand value, total cost is the area under the supply curve out to

Table C-2a: Marginal Cost of Increased Capacity

C Band Re-use:

<u>Increased Capacity in Transponders</u>	<u>Marginal Cost per Transponder</u>
first 216	$m_c Q_c$
next 216	$m_c^2 Q_c$
next 216	$m_c^3 Q_c$
next 216	$m_c^4 Q_c$
.	.
.	.
.	.

Ka Band Introduction and Subsequent Re-use:

<u>Increased Capacity in Transponders</u>	<u>Marginal Cost per Transponder</u>
first 288 (introduction)	Q_a
next 288 (first re-use)	$m_a Q_a$
next 288	$m_a Q_a$
next 288	$m_a^2 Q_a$
next 288	$m_a^3 Q_a$
.	.
.	.
.	.

Table C-2b: Development of the Supply Curve for One Set of Cost Parameters

Parameters: $\bar{m}_c = 1.2$, $Q_a = 1.5$, $m_a = 1.2$

C Band:

<u>Increased Capacity in Transponders</u>	<u>Marginal Cost per Transponder</u>
first 216	1.20
next 216	1.44
next 216	1.73
next 216	2.07
.	.
.	.
.	.

Ka Band:

<u>Increased Capacity in Transponders</u>	<u>Marginal Cost per Transponder</u>
first 288	1.50
next 288	1.80
next 288	2.16
next 288	2.59
.	.
.	.
.	.

Resulting Supply Curve:

<u>Increased Capacity in Transponders</u>	<u>Cumulative Capacity Increase</u>	<u>Marginal Cost Per Transponder</u>
first 216	216	1.20
next 217	432	1.44
next 288	720	1.50
next 216	936	1.73
next 288	1224	1.80
next 216	1440	2.07

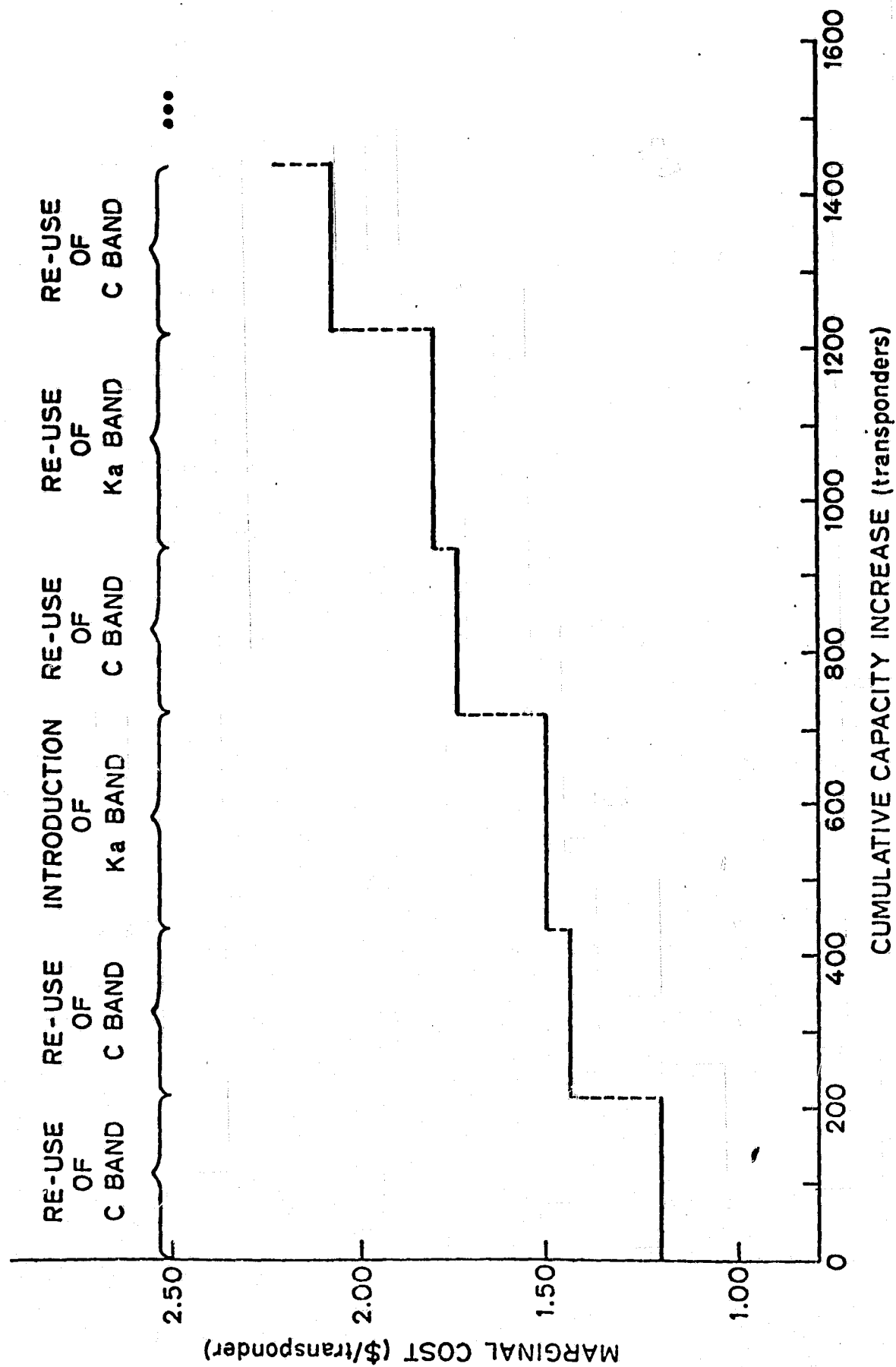


Fig. C-3: Supply Curve Developed in Table C-2b

the demand value. Table C-1 shows how demand was met for each of the branches of the decision tree pertaining to Alternative 3.

Results

Because the data used here is illustrative, no definitive statements can be made from the results. However, it is interesting to analyze the tree in Figure C-2 both quantitatively and qualitatively.

The tree can be rolled back to yield an expected cost of meeting demand for each alternative. The results are:

Alternative 1, (C-band re-use): Expected cost = \$1621

Alternative 2, (Ka band): Expected Cost = \$1802

Alternative 3, (Combination): Expected Cost = \$1171

If Research Programs 1, 2, and 3 were available that led respectively to Alternatives 1, 2, and 3 being available in 1990, then it appears that Program 3 leads to a savings of \$450 compared to Program 1, and a savings of \$631 compared to Program 2. If the costs of the research program were available, the net savings generated could be compared.

In Section II, comparing the full distribution on total demand to the distribution on total capacity led to the conclusion that there is a probability of .86 that demand will exceed capacity if neither re-use or Ka band are available. In the cruder analysis here, we see from

Table C-1 that in no case can demand be met by just the C and Ku bands without re-use. In the case of the lowest demand value, 415 transponders, demand is met either by using 19% of the Ka band or by re-using 25% of the C band. For the higher demand levels of 690 and 1100 transponders, the introduction of the Ka band without re-use is not sufficient to meet demand. It appears likely that re-use will be required by 1990. At the highest demand level, extensive re-use is necessary. We also note that the lowest cost "solutions" involve mixing re-use of the C and Ka bands.

ECONOMIC ASPECTS OF SPECTRUM MANAGEMENT

by

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Abstract

This paper addresses problems associated with the allocation of a scarce resource--the radio frequency spectrum. It is observed that the current method of allocation very likely does not allocate the resource to those most valuing its use. Because users of the spectrum are not required to pay the "opportunity cost" of their spectrum use (defined as the benefits foregone by not employing the resource in its best alternative use) they are, in effect, being subsidized. Furthermore, there is little or no incentive for them to improve and conserve their use of the resource. If anything, incentives run counter to this goal.

A number of schemes to encourage more economically efficient use of the resource have been proposed. These range from institution of a free market in radio frequency rights to implementation of federally administered usage fees. The first part of the paper sets out economic criteria by which the effectiveness of resource allocation schemes can be judged, and offers some thoughts on traditional objections to implementation of market characteristics into frequency allocation.

The second part of the paper discusses the problem of dividing orbit and spectrum between two satellite services sharing the same band, but having significantly different system characteristics. The problem is compounded by the likelihood that one service will commence operation much sooner than the other. Some alternative schemes are offered that, within proper international constraints, could achieve a desired flexibility in the division of orbit and frequency between the two services domestically over the next several years.

I. WELFARE ECONOMICS AND SPECTRUM MANAGEMENT

a. Introduction

Much has been written in recent years about how the Federal Communications Commission (FCC) and the Interdepartmental Radio Advisory Committee (IRAC) allocate a scarce resource - the radio frequency spectrum. The interest in this subject stems from the fact that radio spectrum [1] is allocated in a manner so radically different from that for most other resources in our economy. From the standpoint of economic efficiency, this method of allocation is considered by many to be highly questionable.

The present method of radio spectrum allocation [2] has its roots in the Radio Act of 1927 (Public Law 69-632), the purpose of which was stated in the preamble as follows [3].

"... this Act is intended to regulate all forms of interstate and foreign radio transmissions and communications within the United States, its territories and possessions; to maintain the control of the United States over all the channels of interstate and foreign radio transmission; and to provide for the use of such channels, but not the ownership thereof, by individuals, firms, or corporations, for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, conditions, and periods of the license."

Most of the provisions of this act were later incorporated into the Communications Act of 1934 (P.L. 73-416), the basis of the FCC's current authority. In effect, the federal government nationalized the radio spectrum, apparently out of the fear that continued unregulated use would result in levels of radio interference rendering the resource entirely useless [4].

As "trustee" of the resource, the federal government is charged with the following significant responsibilities:

Sec. 1, ". . . to make available, so far as possible, to all people of the United States a rapid, efficient, nation-wide and world-wide wire and radio communication service with adequate facilities at reasonable charges.

Sec. 303(c), "Assign bands of frequencies to the various classes of stations, and assign frequencies for each individual station and determine the power which each station shall use and the time during which it may operate"

Sec. 303(f), "Make such regulations not inconsistent with law as it may deem necessary to prevent interference between stations and to carry out the provisions of this Act: Provided, however, that changes in the frequencies, authorized power, or in the times of operation of any station, shall not be made without the consent of the station licensee unless, after a public hearing, the Commission shall determine that such changes will promote public convenience or interest or will serve public necessity, or the provisions of this Act will be more fully complied with"

Sec. 303(g), "Study new uses for radio, provide for experimental uses of frequencies, and generally encourage the larger and more effective use of radio in the public interest"

These provisions underlie the present "modus operandi" of the Federal Communications Commission. As it is now, the FCC must decide how, and by whom, radio frequencies will be used [5].

Aside from the issue of the political implications of centralized control of an information medium (certainly not to be ignored in this case), the FCC faces the problem that plagues any central allocatory authority: insufficient genuine information to make intelligent judgments on how to distribute the resource under its purview. This is not to say that applicants and licensees are not eager to supply plenty of information, but it is information inevitably colored to reflect the vested interest of its supplier [6]. Sorting the

genuinely relevant information out of reams of data is an unenviable task often far beyond the capability of an agency with the FCC's resources.

One place market allocation appears to be generally superior to administrative control is in the economy of information required to guide resources to their highest valued use [7]. No single entity needs to know who has the greatest need or who will make best use of a resource. All relevant information about the marginal value of a resource to those actively competing for its use is contained in one number--the market place. In aggregate, the amount of information in the economy can remain immense, but the decentralization of decision-making eliminates the transaction cost associated with transferring large amounts of information to a centralized authority, and tends to ensure that decisions are based only on relevant information [8].

Owen set out three serious flaws in present methods of radio frequency allocation and assignment as follows [9]:

- 1) There is no formal mechanism for trading spectrum rights among users;
- 2) no price is paid for use of the resource;
- 3) the criteria by which users are chosen are vague and, from the standpoint of both quality and economic efficiency, often counter-productive.

Both the first and second flaws have significant impacts upon innovation and the development of new services that often follow it. Spokesmen for the development of new communications services often find themselves in conflict with the FCC over whether or not frequencies

will be allocated to potential new, but as yet non-existent, services. They correctly perceive that failure to secure frequency allocations now for future services may preclude those services from coming into being. Without some assurance that these allocations can be obtained, people hesitate to invest in development and construction of equipment that would be rendered useless by shortages of usable frequencies.

One cause of this dilemma is the effective nontransferability of either present or future radiation rights [10]. Under the present system, there is often no incentive for old users to yield to new, even when the new user would be willing to pay the older user much more than the value that the old user would assign to his unit of spectrum. If old users perceived spectrum use as having a price, either because they paid a fee, or because they could have all or part of their radiation rights bought out by new users, then there would indeed be an incentive for old services to yield use of the spectrum to more valuable new services. In such a world, providers of new services would know that, when the time came, they would be able to obtain frequencies. The only uncertainty would be over what the price would be (even this uncertainty could be reduced by an appropriate futures contract with a present user). From the standpoint of risk, this would be preferable to the current system, where the new service has no assurance that spectrum with the desired characteristics can be obtained in the desired amounts, regardless of its willingness to pay the price.

Certain implications of nontransferability of any rights can be gleaned from the following proposition, derived from welfare economics:

If any number of parties enter into a transaction of their own volition, and if the transaction has only nonnegative impacts on nonparticipating parties, then social welfare is unambiguously increased by the transaction.

If there is a nonparticipating party on which there is an adverse (negative) impact, it may still be possible to expand the definition of the transaction to include compensation to this party and satisfy the above criterion. If parts of such expanded transactions are allowed to be only potential (that is, transactions that could take place but won't necessarily) then the above becomes the familiar "Kaldor Criterion" [11].

If transactions of the type above are blocked, as present communications law dictates that they are, then society has foregone an increase in its welfare. This is the primary reason for the economist's interest in the shortcomings of current radio frequency allocation methods.

In a world of perfect markets, all transactions would be of the type described above (to be perfect, impacts upon nonparticipants should be strictly zero). Furthermore, when certain familiar assumptions are made about the preferences of the participants in this market (nonsaturation, etc.) and transactions costs (they are zero or sufficiently negligible) then the resources allocated by the market will be allocated in an economically efficient manner. This

economically efficient allocation of resources is a necessary, but not sufficient, condition for maximization of social welfare (however, within reason, it may be defined. Arriving at this definition is the essence of the political problem.).

The stated proposition can be applied even when markets are imperfect, though greater scrutiny of a transaction's effects upon the welfare of third parties is generally required. The presence of monopolies may tend to create more equity and externality problems, but it is still possible, within these constraints, to define certain resource allocations as being "better" or "worse" than others.

Besides inhibiting transfer of rights, "zero price" spectrum use reduces incentive to economize on its use. Thus, spectrum (and orbit too) is always perceived as being in short supply. NASA, for example, sets out the coming saturation of limited spectrum and geostationary orbit resources as the motivation for initiating a research and development program to open the 20/30 GHz band to use by communications satellites. Technologies that make use of the resource more extensive (for example, higher power traveling wave tubes making higher frequencies usable) and more intensive (multi-beam antennas, digital compression, etc.) are seen as a way to increase the resource supply, and thus close the gap between supply and demand. Others, however, have noted a tendency of technology based efforts to increase supply to also increase demand, by making new services possible [12]. Thus, the technologist becomes much like the dog chasing its tail--running faster and faster but never quite catching up.

This perceived shortage is a consequence of the fact that no price is paid for use of the resource. In a properly functioning market, no shortage would exist. In such a world, NASA would see its objective not as closing the gap between supply and demand, but as lowering the resource cost to the user (or, alternatively, expanding the number of services that can be offered on a profitable basis). Also, there would be greater incentive for private sector users to develop ways to use the resource more intensively, since this would directly benefit them financially. NASA's emphasis would probably shift towards (higher risk) extensive development.

Finally, conventional cost-benefit analysis will tend to misestimate the return on communications R&D. Many of the "benefits" measured by such analyses are, in part, measures of the cost of misallocating a resource. Many of the services now excluded (or limited) by the present spectrum allocation and assignment process may have greater value than some of those included (a frequently cited example of what appears to be such a case is land mobile radio vs. UHF television frequency allocations). Likewise, costs associated with some high value services now operating will be overestimated due to their being required to use a suboptimal mix of inputs. If the resource were allocated in a manner that was "economically efficient," then one could be sure that it was only marginal services whose costs and benefits were being compared, and that all cost estimates were being based on optimal input mixes. As it is now, most studies of this sort are largely "stabs in the dark."

b. Economically Efficient Spectrum Use

The word "efficiency" is generally used in several different contexts, often leading to confusion. For example, some engineers characterize efficient spectrum use as accomplishment of a given task by use of technology that minimizes required bandwidth, power, and area of unwanted spillover. Under this definition, efficient use of the resource is identified with minimum possible use, even though such minimal use would require state-of-the-art (expensive) technology across the board.

Another (and I would argue more reasonable) approach to judging efficiency of spectrum use invokes economic efficiency as the chief criterion. Economic efficiency is characterized by optimum use of all resources required for production of a given output. Here, "optimum" means minimization of the total opportunity cost of all inputs used to produce a given output. Opportunity cost is defined as the value of benefits foregone by not employing a given input (i.e., spectrum) in its best alternative use. As an aside, it can be noted that, in a perfect market economy, aggregate opportunity cost minimization corresponds to aggregate profit maximization [13]. If the total opportunity cost of all inputs used in a production process exceeds the value of output, then the activity in question is unprofitable relative to other possible activities; thus, one expects resources to flow to the other (more profitable) activities.

Economic efficiency criteria treat spectrum as just one of many inputs into a given output. Furthermore, inputs can be

substituted for each other. For example, one can use less spectrum by using more sophisticated technology, and vice versa. In deciding how much of each to use, the producer (here a common carrier or broadcaster) compares the relative cost of each, and then alters the mix of inputs so as to minimize total cost.

Under the present allocation methods, the cost of spectrum use to the user (zero, assuming one can get the assignment) does not reflect the opportunity cost (which is greater than zero, since use of a given frequency necessarily excludes certain other potentially worthwhile uses of the same frequency in the same area). The result of this is that common carriers, broadcasters and other users of the spectrum are motivated to substitute greater spectrum use, which they perceive as cost-free, for use of more expensive technologies that reduce or eliminate spectrum use. At the same time, potential spectrum users who cannot get an assignment from the Federal Communications Commission (FCC) are forced to substitute alternative resources in the production of the goods or services they wish to provide, or forego production altogether. Under the FCC's current allocation and assignment scheme, there is nothing to ensure that spectrum is allocated among potential users in such a way as to maximize its contribution to society's aggregate economic product, and good reason to believe that it is not.

The solution to this problem is not, as is often proposed, to accommodate all possible users of the spectrum by use of technology sophisticated enough to allow everyone who wishes to use the spectrum to do so. This kind of approach seeks to reduce the opportunity cost

of spectrum use to zero by substitution of other resources (such as more sophisticated equipment), but fails to recognize that this requires an increase in the opportunity cost of the other resources used in the production of a specified level of output. The total opportunity cost of all inputs is unlikely to be minimized by such an approach.

The best (in the sense of economically efficient) solution to the spectrum allocation problem can only be achieved if the cost of spectrum use to the user can be made to reflect its opportunity cost. If this could be achieved, competitive economic forces would then tend to push spectrum assignments into the hands of those groups or individuals making the most economically productive use of the resource.

If the cost of the spectrum use truly reflected opportunity cost, spectrum use by new industries (such as a Land Mobile or Broadcast Satellite Service) that proved to be more profitable than existing uses would drive up the cost of spectrum use to the point where the existing users would be forced to reduce or eliminate their use. Thus, new communications services would not face uncertainty about whether or not spectrum assignments could be acquired that might otherwise stifle their growth.

There are a number of ways in which the cost of spectrum use could conceivably be made to reflect opportunity cost. Among these are institution of a free market for spectrum where assignments can be bought and sold, institution of a spectrum use fee by a centralized regulatory authority, or some mix of markets and regulation. The

market's approach alleged drawback resides in the difficulty of defining and enforcing spectrum property rights (although it can be effectively argued that this same problem plagues the current system). The drawback to centralized allocation with usage fees is that an overwhelming amount of information is required in order to accurately calculate fees that reflect opportunity cost (the shadow pricing problem).

Nevertheless, definite improvement in the current FCC allocation and assignment process can very likely be achieved, even though a "best of all possible worlds" solution may be impossible. Allowing parties now holding licenses to openly buy and sell all or part of their frequency assignments would institute market characteristics tending to lead to more efficient spectrum utilization. In spite of the evident merit of applying such market mechanisms to the allocation of spectrum, however, there remain some traditional objections that must be addressed [14].

c. The Property Rights Problem

It is generally agreed that market mechanisms cannot be successfully introduced into spectrum allocation without first arriving at a workable definition of spectrum property rights. It has been argued that transferable rights for a resource as ethereal as the radio spectrum could become very complicated indeed. For example, determination of who is liable for interference experienced by a certain party would not be trivial in the case where the interference is caused by intermodulation (although, again, this is

no different from the current situation). However, it would be premature to conclude, based on this alone, that enforcement costs [15] for transferable spectrum property rights need be prohibitively high.

The relatively low cost of enforcing property rights in more "concrete" resources, such as land, does not result from the definition of these property rights being any simpler than those proposed for spectrum. A small amount of reflection on the nature of land property rights reveals that they are, in fact, a very complicated set of rights, none of which are absolute in nature. For example, landowners may keep trespassers out, but not kill them; grow corn, but not marijuana; make noise, but not so much that their neighbors can never sleep. Zoning laws make these rights even more restrictive. Land property rights are never exclusive in the sense of society abdicating all control over land use.

It is not so much the level of complexity in a right's definition that determines enforcement costs, but certainly what the right entails. If A uses B's land without B's authorization, there is little doubt that a court will find A liable for damages to B. Certainly about what the outcome of an adjudication will be tends to deter events of this kind from occurring. The disputes most likely to end up in court are those associated with fuzzy delineation of a right. For example, the level of noise A is allowed to make on his/her property is generally not well defined. If A's turbine test facility is sufficiently close to neighbor B's recording studio, one expects there is a good chance the two will end up in court. Sufficient

precision in the definition of property rights would go far towards keeping spectrum users out of court.

The other component significantly affecting enforcement cost is the cost of detection. In the land rights example, it was reasonable to assume that B would detect A's violation of B's property right with high probability at very little cost. However, if the probability of detecting A's violation (and identifying A as the offender) is sufficiently low, and the penalty incurred by A upon being detected is sufficiently low, one might expect A to violate B's right even when it is certain that A would lose to B in an adjudication.

This last problem can be formally illustrated in the following manner:

- a = state of the world in which A's violation goes undetected;
- b = state of the world in which no violation takes place;
- c = state of the world in which A is caught and punished;
- p = the probability A assesses of being caught;
- $u(x)$ = utility of state of the world x.

Making the assumption that $U(a) > U(b) > U(c)$, construct the function $(1-p)U(a) + pU(c)$. This is A's expected utility of violating B's right, and is a strictly decreasing function of p. Furthermore, there exists a p between 0 and 1 such that $U(b) > (1-p)U(a) + pU(c)$ for all probabilities greater than p. That is, above some minimum probability of detection, A will not wish to violate B's right. If one accepts the notion that the perceived probability of detection tends

to be positively correlated with society's actual expenditure on detection, then one can conclude that an increase in this expenditure will tend to decrease the number of people violating other people's rights. Whether the expenditure that maximizes the net social dividend (defined as the value of the provisions prevented minus the cost of detection) will be within reasonable limits is an as yet unresolved question for spectrum rights.

Also, observe that an increase in the penalty for a violation would decrease $U(c)$ and, therefore, the minimum detection probability above which A would not violate B's rights. Thus, under both the current and market techniques for spectrum allocation, there is some flexibility in that higher penalties can be, to some extent, substituted for detection capability, thereby lowering enforcement costs [16].

DeVany et al. [17] have proposed definition of spectrum property rights in terms of hours of transmission, in and out of band limits on radiated power outside a specified geographical area, and bandwidth. The notion is that property rights defined in these "output" terms would be much easier to transfer in whole or part than rights specified in terms of inputs, such as transmitter power or antenna height. In the case of satellites, system performance requirements are already defined in terms of limits on power-flux-density (PFD) over specified geographical areas. This closely approximates the Time-Area-Spectrum (TAS) property right advocated by DeVany et al., though additional complications are introduced by the possibility of interference on earth to space transmissions, especially when the

power levels of these uplinks differ significantly. These additional complications manifest themselves in the form of the resource called "orbit." Segments of the geostationary arc in space are the counterpart of areas of geographical coverage on earth. Any discussion of satellite systems must account for both.

d. Spectrum Monopoly

Besides enforcement costs, concern has been voiced over the strong possibility that markets in radio frequencies would be largely monopolized by the national broadcasting networks in some bands, and by AT&T in others, in an attempt to squeeze out competition. This tendency could be especially severe in the case of AT&T where regulated rate of return monopoly services could be used to cross-subsidize services offered in competitive markets. In principle, AT&T might attempt to squeeze out competitors by buying up spectrum, thereby raising its price to competitors and reducing the volume of services they are able to offer. The standard response to this concern--that antitrust laws can respond to such efforts in the usual manner--is not entirely satisfactory in a time when many large corporations have already demonstrated the capability to drag such proceedings out for years. It would be far preferable to avoid this situation if at all possible.

On the other hand, there are numerous ways in which the telephone company can cross-subsidize services without resorting to spectrum hoarding at all. Spectrum hoarding would succeed as a

squeeze out technique either by completely excluding competitors from use of the spectrum or by forcing them to charge higher prices, allowing the monopoly to undercut them. Total exclusion would seem to make what is occurring too obvious. Hoarding just enough to drive up the competition's prices to where they can be undercut would seem to be a roundabout way of achieving something that could be more easily achieved without hoarding spectrum (i.e. instead of buying up spectrum to hold idle, why not just directly undercut the competition's price?).

Finally, it is not clear that a spectrum market heavily dominated by a regulated monopoly would be worse than the current situation, nor is it clear that the AT&T monopoly is any more constrained by the current FCC from undesirable market practices than they would be if spectrum were allocated by the market place. There is no reason to believe that monopoly or oligopoly could not be just as effectively regulated within the context of a market system as without. This particular objection is largely beside the point.

e. Equipment Lifetimes

An oft-cited argument for maintaining the status quo is that the rigidity of present spectrum allocation methods is necessary to protect the integrity of investment in long-lived radio equipment. The fallacy of this argument lies in the failure to distinguish between the "technical" and "economic" lifetime of equipment. Technical lifetimes may be very long indeed, but it is the economic lifetime that is relevant in economic decisions. Tax and depreciation policies

in the United States, coupled with the rate of innovation and resulting shifts in demands, tend to make the economic lifetimes of most technologies significantly shorter than their technical lifetimes. Innovation in the computer industry, for example, has been so rapid that most machines are scrapped and replaced long before there is any danger of their wearing out.

Economic decisions always involve the comparison of present and expected future alternatives in the present moment. One does not continue to fly Ford tri-motors simply because the equipment has not worn out if conditions of demand are such that the profitability of flying jet aircraft is greater. In fact, one of the strongest arguments against the rigidity of the present system may be that it stifles innovation in communications by favoring existing users at the expense of innovative new users. Airlines wishing to fly new aircraft have little difficulty obtaining pilots or fuel used by airlines operating older aircraft when conditions of demand warrant it, but anybody wishing to offer a new radio service may have great difficulty obtaining spectrum from existing users, even when the demand for the new service is high.

f. Indirect Prices for Resource Use

A not uncommonly heard objection to pricing spectrum use per se is that users already pay an indirect price through their investment in radio equipment and operating expenses. However, attempting to apply this argument to other analogous situations in the economy reveals its weakness. Cars and gasoline, for example, like radio

equipment and radio spectrum, are both complements and substitutes (i.e., more fuel efficient cars can be substituted for greater gasoline consumption, yet the two are always used together). One would be on very weak ground indeed if one attempted to argue that, because people must buy cars to use gasoline, charging a price of zero for gasoline would not lead to inefficient use of the resource. Based on this premise, one could make a strong case that the government should completely subsidize gasoline use for reasons of equity.

If any conclusion can be reached from the ongoing debate over the viability of spectrum markets, it is that further theorizing is unlikely to resolve the question. The economic case has been made. Just as the theoretical physicist must at some point take predictions to the laboratory before further theoretical progress can be made, so it is that economists, both pro and con, must attempt an "experiment" on the viability of spectrum markets before confidence can be placed in their conclusions. Such an experiment for land mobile radio services has already been proposed by Dunn and Owen [18]. Along these lines some thoughts on how market techniques could be applied to the assignment of orbit-spectrum to satellites are presented in the next section of this paper.

II. MARKET ALLOCATION OF ORBIT-SPECTRUM FOR SATELLITE SERVICES

At the time the first man-made earth-orbiting satellites were launched, few expected or believed possible the explosion in the use

of communication satellites that has occurred. Yet, problems resulting from this rapid growth illustrate the drawbacks in the current method of frequency allocation and assignment. There are few places where the need for administrative flexibility is more apparent than in the allocation and assignment of frequencies to services undergoing rapid technologically induced changes.

From the standpoint of system performance, optimum frequencies for satellites lie between about 1 and 10 gigahertz--the so-called "space window." Because this part of the spectrum was already heavily occupied by the time communication satellites went into service, only one of the three bands currently allocated to communication satellites falls within this region (4/6 gigahertz band). The other two bands (12/14 gigahertz and 20/30 gigahertz) require substantially higher transmission powers to overcome effects of atmospheric attenuation. Of these, the 12/14 gigahertz band is only now coming into use while the technology to make the 20/30 band useable remains in the future. It is highly doubtful that the present approach to frequency allocation has minimized the aggregate cost of providing all services, both space and terrestrial, using frequencies above one gigahertz.

Before proceeding with the discussion of orbit and frequency allocation for satellite services, it is necessary to consider the international context of the orbit-frequency allocation and assigned problem.

The International Telecommunications Union (ITU) allocates frequencies to services on a worldwide basis. This is achieved through

administrative radio conferences in which ITU member nations attempt to arrive at a consensus as to how radio frequencies will be used.

Because its success is based on consensus politics, the ITU must attempt to minimize the international constraints on domestic decisions about frequency use within a particular country. The United States, for one, has traditionally argued for the maximum flexibility in determination of how a nation will use frequencies within its borders. Services offered in one part of the world frequently will not even exist in another part. Consequently, strict worldwide allocation of frequencies would lead to tremendous waste in resource use.

The U.S. is fortunate in the respect that, within its region of the world, only a handful of nations are in potential conflict over use of orbit and spectrum. This contrasts with the European situation where many developed nations are concentrated within a relatively small geographical region. Thus, it was tentatively concluded by a 1974 Rand Corporation report that, except for Canada, the probable demand for satellite systems of other countries in the western hemisphere (ITU Region 2) can be met without special coordination with U.S. systems [19]. In fact, most of the orbital arc best suited for use by South American nations does not coincide with segments best suited for U.S. and Canadian systems.

If this conclusion is indeed true, then reliance on market techniques for domestic satellite orbit-spectrum assignment becomes a much simpler political problem internationally than if domestic and international assignments cannot be decoupled. More is said about this shortly.

While people tend to describe satellite systems in terms of the services they provide, it is often useful to think of them purely in terms of their system characteristics. High-powered satellites, such as those being considered for space broadcasting, offer the possibility of small diameter (less sensitive) earth station antennas, thus allowing for systems employing many relatively cheap earth stations. Systems in the fixed satellite service generally employ relatively few earth stations using large diameter (more sensitive) antennas and low powered satellites. Interference between the two types of systems tends to be more severe than interference between systems of the same type. Two reasons for this are, 1) even though larger antennas have relatively high gains, they also have sidelobes that can be illuminated by interfering satellites and, 2) when the interfering satellite is transmitting a higher power density than the satellite transmitting the desired signal, then illumination of the sidelobe results in relatively more interference noise in the receiver.

Approaches to sharing between services using the two system types described have been studied relatively extensively and are fairly well understood [20]. The unsolved problem lies not in how to share between the two services but in how to determine, on the basis of future utility, how much orbit-spectrum must be received for each. If the future demand and course of technological development for each service could be predicted with certainty, there would be no problem in deciding how much orbit-spectrum to allocate to each service at any given time. The difficulty arises both from the

likelihood that one service--the fixed satellite service, will grow more rapidly within the next few years than the other--the broadcast satellite service, and from uncertainty about what technologies will become available to alleviate sharing problems between the two.

One question one might ask is: Should spectrum be held idle for the future use of a service that might possibly come into existence but is not certain to do so? Holding spectrum idle necessarily excludes its use by currently viable services. The opportunity costs incurred may very well outweigh the discounted future benefits of the service for which the spectrum is being reserved. It is unlikely that a satellite service expected to come into existence many years down the road could be justified if this were to require that a significant amount of usable spectrum be held idle for this entire period.

At least one person, Dr. Charles Jackson, has proposed a worldwide orbit-spectrum market for satellites [21]. Under the Jackson proposal, orbit-spectrum rights are preallotted to each ITU nation. Nations may then lease their rights (which specify a band of frequencies and a certain number of degrees of the geostationary arc locationally unspecified) to the highest bidder through a market run by an international body (the IFRB). The rent from the lease of an orbit-spectrum right goes to its "owner." Once a system operator has acquired enough rights to protect himself from interference, he registers his satellite system with the IFRB, just as at present.

Jackson's premise is that this approach would defuse much of the growing political opposition that developing nations have to use

of the orbit and spectrum by the developed nations without requiring that economic efficiency be sacrificed. Jackson states that, "the arguments for the necessity and possibility of a spectrum market for international satellites are even stronger than the arguments for the use of market allocation for many domestic spectrum uses. Both equity and efficiency considerations are involved in the allocation of the orbital-frequency resource. A well designed market system should be able to separate these two problems" [22].

Unfortunately, there is reason to question the last statement. Much of what occurs in the international forum is heavily colored by ideology that may not even accept the principles outlined by Jackson and the first part of this paper. Even if orbital slots that could be sold or leased were preallocated to every nation in a manner deemed equitable (a proposal counter to traditional U.S. positions), several political problems would still remain. Some nations, initially finding relatively few buyers for their orbital rights (and all buyers being from developed nations), might see themselves as victims of the monopsony power of the developed nations. Coalitions of nations might decide that the political advantages gained in other areas by using their allotted orbit-spectrum rights for leverage would outweigh the relatively small revenues they might receive from leasing them to users.

Problems of both sorts above have stalled the United Nations Conference on the Law of the Sea for a number of years on the question of deep seabed resource development. One can make a reasonable case

that leasing of deep seabed tracts by an international authority to high technology companies for a limited term of years at a price roughly approximating the economic rent of the activity is an equitable way to proceed with the development of deep seabed resources, especially when the proceeds from the lease are redistributed to lesser developed nations. However, it is only recently, after several years of negotiation, that some of the lesser developed nations have begun to acknowledge that only the economic rent, and not the entire revenue, from these activities should be subject to redistribution. Many nations, seeing that they have little to gain at best from deep seabed resource development, have sought to use the issue for political leverage. There is reason to believe that much of the same kind of thing would make implementation of the Jackson proposal on a worldwide scale difficult, regardless of merit. However, it might be possible, as will be discussed, to employ a regional or even domestic variation of the Jackson plan.

At present, three approaches to allocation of the 11.7 to 12.7 GHz (downlink) band appear to have reasonable probabilities for adoption in ITU Region 2:

1. Rigid Allotment Plan with EIRP's, orbital spacing, frequency assignments specified; slots, channels assigned to nations.
2. Continuation of first-come, first-served principle; fixed and broadcasting satellites sharing the band, broadcasting satellites constrained to orbital arc segments from 75° - 95° W (North America) and 140° - 170° W.

3. Continuation of first-come, first-served principle, separation of services by frequency.

The third approach listed characterizes the expected U.S. position at the 1979 World Administrative Radio Conference. However, there are two ways to divide fixed and broadcast satellite services by frequency, only one of which is acceptable to U.S. interests. For example, the FCC's Tenth Notice of Inquiry (Docket 20271) recommended that the broadcasting satellite service be given a primary allocation in the 12.2 to 12.75 gigahertz band (shared with terrestrial fixed and broadcasting services), and that the fixed satellite service be given a primary allocation in the 11.7 to 12.2 gigahertz band. This arrangement would require either a power-flux-density limit on broadcasting satellites or a detailed frequency coordination plan between broadcasting satellites and terrestrial services, and would cause decreased geographical flexibility. Too stringent power-flux-density limits might preclude the use of earth terminals small enough for low-cost direct satellite-to-home broadcasting.

While some (mostly Region 2 countries interested in satellites primarily for broadcasting) deem this last aspect to be bad, the economist would note that if the value of the additional fixed satellite services that can be offered because of power-flux-density limitations outweighs the additional value of direct broadcasting from satellite to home (as opposed, for example, to broadcast from satellite to community area TV reception stations) then this would be the economically efficient solution. High powered broadcast satellites required

for direct broadcast may require the use of more orbit and spectrum than is justified by the additional aggregate economic value.

Lower powered broadcast satellites broadcasting to community area TV reception stations would generally allow more fixed satellite services to be offered in the same segment of orbit.

Although this latter solution very likely is the one that maximizes the aggregate economic value of the services using the band, most of the benefits from this approach accrue to nations not wishing to use broadcast satellites (mostly developed nations). Even though aggregate economic value is maximized, all parties may not be better off than under alternative schemes. Unless some way is found to redistribute benefits among nations (Jackson's satellite market being one possibility) under the plan proposed by the U.S., stiff opposition can be expected.

An alternative suggested allocation includes both broadcasting and fixed satellites in the 11.7 to 12.75 gigahertz band, with higher powered satellites (i.e., broadcasting) initially assigned to the 11.7 and 12.2 band and lower powered satellites (in the fixed satellite service) initially assigned to the 12.2 to 12.75 gigahertz band. It has been argued that this proposal makes (technically) efficient use of the orbit and spectrum by grouping satellites of similar characteristics and initially constraining higher powered satellites to those frequencies shared with few terrestrial services (making sharing with terrestrial services easier). One objection to this flexible assignment scheme is that accommodations for broadcasting satellites could disappear if faster-growing fixed satellite

services end up requiring the lower part of the band as well.

Allowing the fixed satellite service to use the lower part of the band at all may incur international opposition from other Region 2 countries wishing to use this part of the band only for broadcasting satellites. On the other hand, insistence by these countries that the 11.7 to 12.2 gigahertz band be held idle indefinitely, even in the face of expanding demand for fixed satellite services, might be unacceptable to the U.S., and very likely economically inefficient.

If frequency division of the sort proposed by the U.S. is not adopted at WARC 79 (and this is considered by many to be unlikely), then the U.S. will be faced with the likelihood of an orbit segmentation plan (approach #2 above) or an even less desirable allotment plan (approach #1). One conclusion from the preceding discussion is that, however undesirable the approach ultimately adopted is, the U.S. would be much better off if the orbit-spectrum rights adopted are marketable (transferable) than if they are not. Then, at least, the F.C.C. could go into the world market to buy them or lease them from other nations, if the domestic demand for satellite services warranted their doing so. If the adoption of a rigid plan appears imminent, it might be in the best interest of the U.S. (and other nations with similar concerns) to push for a regional market approach.

Even if such an approach proves to be infeasible throughout Region 2, it might still be feasible for a limited number of nations (i.e., Canada, the U.S., Mexico, Brazil) to collude and pool their allotments in order to achieve the maximum economic value from their

allotments (the market scheme would have to, of course, distribute rents so that each participating party is better off than they would be without such an agreement, but this is one thing the market is well suited for). Mexico, for example, could lease their slots to a foreign party until they were ready to use it themselves (thus, making both better off). Even if no other nations wished to participate in such a scheme, the U.S. could still employ the market approach in domestic distribution of its allotment. Three approaches that could be employed domestically or regionally are described in the following pages:

Policy Option 1 - A Domestic or Regional Market for Orbital Slots

Orbit-spectrum slots are auctioned to the highest bidder. These assignments may then be bought and sold between services if no affected parties are bypassed. The rights auctioned could be defined in a manner similar to the Time-Area-Spectrum right proposed by DeVany et al., but would have both earth to space and space to earth components. On the space to earth component, both in band and out of band maximum permissible power-flux-densities could be stated for areas outside the designated geographical area of coverage (with the out of band limit applying within this area as well). The earth to space component would have analogous limits (not necessarily the same) on in band power levels outside the designated portion of the geostationary arc and out of band power levels generally.

Rights bought by the highest bidder would be perpetual, but transferable. As long as nobody else's rights are affected, parties

could even agree to alter power-flux-density limits as well as the amount of the earth's surface and geostationary arc designated by the right [23]. Furthermore, the relatively small number of systems would make enforcement of these rights fairly easy. Thus, the fixed satellite services, which would presumably be the initial rights holder, could at a later date, within the limits of their ability to share their assignment with a broadcasting party, sell all or part of their rights to a broadcasting party for a sum of money. The broadcasting party would presumably buy up additional orbit-spectrum rights from fixed service parties as long as their marginal revenue product from use of the resource exceeded that for the fixed satellite service.

Policy Option 2 - Administered Total Services Discounted Cost Minimization

The idea in this proposal is that both satellite services share frequency allocations and any time a new system, whether broadcasting or fixed, is proposed, the F.C.C. (or the relevant multinational regulatory authority) must include this additional system in the available orbit-spectrum at the lowest aggregate cost over all users. This approach might require the new system to employ more expensive (spectrum conserving) technology than had been anticipated. It could also require previous systems using equipment requiring much orbit-spectrum to change equipment. Which systems must change equipment depends on what combination of changes admits the new system at the lowest aggregate cost.

This policy option is essentially the approach proposed by Lusignan and Russell, in which the party that saves the most gigahertz-degrees

per dollar expended is the party required to conserve spectrum. It differs from coordination (the current procedure for transfer of orbit-spectrum rights) in the respect that no transfer payments between parties need take place for the efficiency of use to be improved. Thus, earlier users need not receive scarcity rents at the expense of later users, as is now the case. Unfortunately, in order for the Lusignan-Russell scheme to work, regulatory authorities must have all the information about technological options and costs available for each satellite system. It is questionable whether this is even remotely possible, and it is the author's opinion that the information problems associated with administrative remedies in general probably make the Lusignan-Russell proposal less attractive than the other more market-oriented policy options presented in this paper.

Policy Option 3 - Leased Rights Distributed by Auction

This proposal is similar to Option 1, except that rights are leased by the central authority rather than sold outright. In fact, the two could be mixed in a hybrid "bonus bid/royalty" scheme if this were deemed desirable.

The least rate would be a floating rate adjusting continuously to the market value of assignments in the relevant part of the spectrum. This, unlike the outright market sale, would ensure that the governing authority accrues all "windfalls" (which, however, could be negative should the market price decline).

One argument favoring this approach over the outright market sale is that bureaucratic organizations would be much more prone to

reexamine their resource needs if they leased rather than bought spectrum. On the other hand, leasing at a floating rate would burden the user with uncertainty over future prices that would not be faced in an outright sale. Businesses will generally pay a premium to reduce uncertainty about the environment in which they expect to be operating, especially when they are contemplating longer-term investments. Furthermore, prices would have to increase dramatically for a true windfall to occur in an outright sale of spectrum assignments. Nevertheless, this option offers an alternative for those who feel that any kind of windfall accruing to a private party under any conditions is unacceptable.

In fact, the choice of lease or sell could conceivably be based on the particular nature of the parties involved. Alternatively, leasing together with encouragement of options or futures contracts could be employed. Under either system, coalitions of parties offering different services that could share an assignment would be capable of offering higher bids than a single service that excluded the use of all other services from that part of the orbit spectrum. Both would tend to lead to more efficient use of the resource.

Several observations can be made about the three policy options described above. First, economic efficiency need not be coupled to distributional equity. In fact, because economically efficient use maximizes the aggregate economic value derived, it is possible that nations participating in an economically efficient allocation scheme could all be better off than they would be under an inefficient

alternative (such as nontransferable nation by nation assignment of channels and orbital slots). This last observation suggests the possibility of multilateral collusion to adopt market or quasi-market techniques in ITU Region 2 for assignment of orbit-spectrum. Such a scheme could even be embedded by agreeing nations within the rigid plan being advocated by some nations, provided transferability of allotted orbital slots or frequencies is maintained. Such an approach should be examined as a possible fallback, should U.S. positions at WARC 79, or at the proposed 1983 Region 2 conference be rejected.

A more important observation is that all three schemes give the designers/operators of satellite systems the incentives to make correct trade-offs between technology and orbit-spectrum resource use--incentives that are either absent or distorted in the present (zero-price rationing) administrative approach. Instilling the correct incentives will be especially important if the number of satellite orbital slots available to the U.S. is severely limited by international orbit-wide planning. In fact, it is possible that the same mechanisms that instill these incentives (payment of scarcity rent by users) could play a role in reducing the attractiveness of such worldwide planning even to those nations most enamoured with it. Once the appearance of users getting something for nothing is eliminated, the international political interest in orbit-spectrum assignment might disappear.

III. EPILOGUE

Orbit-Spectrum is the only commercially useful space resource developed by mankind so far, but, hopefully, not the last. For those who believe other space resources will indeed be developed, orbit-spectrum serves as a useful prototype highlighting some of the problems development of other space resources can expect to encounter.

Fifty years ago, orbit-spectrum was a worthless resource. Today, this is far from being the case, as the continuing political conflict between nations over its allocation so vividly illustrates. Many of the lesser-developed nations have demanded that they be apportioned their fair share of the resource, even though they have no real intention of using it themselves. But, what made this once worthless resource so valuable?

The answer to this last question is, of course, technology--specifically, technology developed by a handful of industrialized nations. One might argue that, since orbit-spectrum is a nondepletable resource made useful only by the investment of these nations, it is only fair that they use it as they see fit. According to this view, leasing of orbital slots through an international authority would lead to accrual of economic rents by lesser developed countries (LDC's) not truly earned--thus, a leasing arrangement would be really quite generous to the LDC's.

Unfortunately, the LDC's don't see it this way. Some believe, rightly or wrongly, that the wealth of the industrialized nations was

accumulated by exploitation of what are now lesser developed nations during the colonial period. They view orbit-spectrum as one of many "common heritage" resources (i.e., not by their location naturally belonging to any one nation) that should be evenly distributed among the nations of the earth, but are likely to be appropriated by the (first-come) industrial nations. That the resource is now rationed free of charge strongly reinforces the plausibility of the view that a "common heritage" resource is being unjustly appropriated by the industrialized nations.

An international leasing market would result in income redistribution that might defuse the militance characterizing some LDC's recently but not destroy the incentives of the industrialized nations to continue technological development improving resource utilization.

It would be naive to believe, given what has transpired in the case of the first renewable space resource, that the U.S. would not receive a great deal of political heat for exploiting nonrenewable space resources, such as space minerals. Any future "space policy" must be prepared to address this problem on at least the rhetorical level, though it's not so far-fetched to imagine world politics leading to the creation of an international authority to lease space mineral rights [26].

The other question of interest only briefly discussed in the body of the paper concerns how the channeling of research and development funds is affected by the assessment of a resource's value. Because there are not market prices for "orbit-spectrum," there is

a tendency to improperly compare different parts of the same resource. For example, the 30/20 gigahertz band is not as easily usable (hency valuable) as the 6/4 band. Yet, the two are described as almost perfect substitutes in R&D discussions. Proper valuation would give a better measure of the return on both extensive and intensive development, and thereby a better idea of where to spend public R&D moneys.

Notes

1. Rather arbitrarily defined as frequencies between 0 and 300 gigahertz (GHz). 1 gigahertz = 1 billion cycles per second.
2. The word "allocation" has two meanings in this paper. The usual meaning refers to the distribution of economic resources in general. The specific meaning refers to the process by which classes of services are allotted a region within the spectrum. It is hoped that which meaning is intended will be clear from the context.
3. Section 301 of the Communications Act of 1934 contains essentially the same language.
4. Ronald Coase argues that the Congress overreacted by passing the Radio Act of 1927, adopting a solution far more encompassing than avoidance of destructive interference required. He argues that the courts would have, in time, arrived at a workable definition of radiation rights optimizing the level of destructive interference even with no legislation at all. Coase, Ronald H., "The Federal Communications Commission," Journal of Law and Economics, II (Oct., 1959). Charles Jackson counters that the importance of interference-free radio communications to the safety of maritime operations (the primary user of radio spectrum in the early part of the century) and the then relative simplicity of an administrative solution (prior to an era when billions of dollars could hinge on the outcome of a decision, or for that matter, when spectrum was even noticeably scarce) makes the "press for government monopoly more understandable." Jackson, Charles L., "Technology for Spectrum Markets," PH.D. Dissertation, MIT, 1976.
5. Descriptions of the allocation and assignment process appear in Coase, op. cit., and Robinson, John O., "An Investigation of Economic Factors in F.C.C. Spectrum Management," F.C.C. Report No. SAS 76-01.
6. A discussion of this information overload problem appears in Robinson, Glen O., "F.C.C.: An Essay on Regulatory Watchdogs," Virginia Law Review, Vol. 64, 1978.
7. There are, of course, a number of nontrivial assumptions being made here about what constitutes "highest value" in a social sense. However, even when social value is somehow determined to differ from market price, there are still ways to employ market mechanisms, and their attendant information economies, to the distribution of resources. For a discussion of this problem see Schultz, Charles, The Public Use of Private Interest, Brookings Institution, Aug., 1977.

8. In fact, many view price systems as nothing more than a highly efficient information system serving to promote mutually beneficial transactions between parties.
9. Owen, Bruce M. "Spectrum Allocation: A Survey of Alternative Methodologies," Office of Telecommunications Policy Staff Paper, April, 1972.
10. Coase, in a footnote on page 27 of his article (op. cit. note 4), remarks that his most fundamental complaint is that certain desirable market transactions are impossible under current law.
11. Henderson and Quandt, Microeconomic Theory, 2nd ed., p. 279, McGraw Hill, 1971.
12. Robinson, John O. "Introduction to Economic Factors into Spectrum Management," Masters Thesis, p. 28, Annenberg School of Communications, Univ. of Pennsylvania, 1974.
13. Note that opportunity cost minimization is not the same as accounting cost minimization. The latter is minimized by zero output whereas the former is not--idle resources have a positive opportunity cost.
14. Not that I am the first to address them--indeed, many have. However, no matter how many times they are addressed they crop up again and again.
15. As used here, "enforcement" includes both detection of a violation of somebody's rights, and adjudication for purposes of resolving disputes over rights or punishing offenders.
16. This crude model is designed only to illustrate a point. Note that it is not capable of handling the more likely situation where A's violation of B's right is unintentional. The simple model could be extended by allowing A either to expend an amount e to be assured he is violating nobody's rights, or expend nothing and face probability q that he is violating somebody's rights. Letting b^* be the state of the world in which A has expended e to be sure that no violations have occurred, the decision criterion becomes:

$$U(b^*) > (1-q)U(b) + q[(1-p)U(a) + pU(c)]$$

If e depends on q in an appropriate way (i.e., $q > 0$ then $e > 0$ and $b^* > b$) and $U(a) > U(b) > U(c)$, then there will always be a p between 0 and 1 such that for all probabilities greater than this p , A will expend e to guarantee that he is violating nobody's rights. If feelings of guilt accompany a violation

16. (continued)

of somebody else's rights then it may be that $U(b) > U(a)$. If this were true for everybody in society, then, according to the simple model, no violations would occur, even if society spent nothing on detection ($p=0$). Thus, the social purpose of guilt may be largely that of keeping enforcement costs down.

As for the trade-off between detection probability and punishment, Gary Becker has noted that "a common generalization by persons with judicial experience is that a change in the probability has a greater effect on the number of offenses than a change in the punishment. . .," Becker, Gary S. "Crime and Punishment: An Economic Approach," Journal of Political Economy, pp. 169-217, March-April, 1968.

17. DeVany, Arthur S., Eckert, Ross D., Meyers, Charles J., O'Hara, Donald J., & Scott, Richard C. "A Property System for Market Allocation of the Electromagnetic-Spectrum: A Legal-Economic-Engineering Study," Stanford Law Review, XXI, pp. 1499-1561, June, 1969.
18. Dunn, Donald A., & Owen, Bruce M. "Policy Options in Mobile Radio Spectrum Management, Report to the F.C.C., Sept., 1978.
19. Reinhart, Edward E. "Orbit-Spectrum Sharing Between the Fixed-Satellite and Broadcasting-Satellite Services with Applications to 12 GHz Domestic Systems," NASA Report R-1463, p. 189, May, 1974.
20. For example, Reinhart's report, previously noted.
21. Jackson, Charles L. "Technology for Spectrum Markets," Ph.D. Thesis, p. 71 ff., MIT, 1976.
22. Ibid 21.
23. How negotiations of this kind might be effected is extensively described in the article by DeVany, Eckert, Meyers, O'Hara, and Scott, referred to in note 17.
24. Russell, S. P., & Lusignan, B. B. "A Techno-Economic Approach to U.S. Domestic Satellite Orbit-Spectrum Regulation," IEEE Compatibility, Vol. EMC-19, No. 3, p. 351, Aug., 1977.
25. This approach is discussed in detail by Jackson in "Technology for Spectrum Markets," op. cit. note 21.

26. For those to whom this seems too "far out," I would only point out that the same could have been said 100 years ago about the idea that apportionment of deep seabed resources would someday become the politically heated issue it has in fact become in recent deliberations at the Third U.N. Conference on the Law of the Sea.

**COST COMPARISON OF COMPETING LOCAL DISTRIBUTION
SYSTEMS FOR COMMUNICATION SATELLITE TRAFFIC**

by

Fred Dopfel

October, 1979

NASA Contract NASW 3204

Report No. 26

PROGRAM IN INFORMATION POLICY

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Abstract

The purpose of this paper is to describe the boundaries of market areas which favor various means for distributing communications satellite traffic. The distribution methods considered are: control earth station with cable access, rooftop earth stations, earth station with radio access, and various combinations of these methods.

The method of comparison is to determine the least cost system for a hypothetical region described by number of users and the average cable access mileage. The region is also characterized by a function which expresses the distribution of users.

The results indicate that the least cost distribution is central earth station with cable access for medium to high density areas of a region, combined with rooftop earth stations or (for higher volumes) radio access for remote users.

Introduction

Technological improvements increasing satellite capacity and lowering costs are likely to continue, implying that the long haul portion of telecommunications costs will steadily assume less importance. This paper focuses on least cost configurations for local distribution of satellite traffic, which is likely to account for an ever increasing portion of telecommunications cost.

The local distribution problem is non-trivial because of the different approaches and technical alternatives for meeting demand that are available. In general, existing common carriers favor use of large earth stations and local distribution provided by existing facilities. Current plans call for only five Western Union earth stations and only seven joint AT&T/GTE earth stations. New entrants, on the other hand, prefer to avoid distribution over existing facilities, instead relying on smaller units which can be placed on customer premises. The latter approach is exemplified by the Satellite Business Systems (SBS) proposal for small rooftop earth stations. In the SBS case, the local distribution cost is insensitive to distance. An alternative approach, the Xerox Telecommunications Network (XTEN), employs an MDS (radio) system for local distribution. The XTEN system's distribution cost is basically independent of distance, although reception is limited to points within about forty miles of the transmitter.

The presence of the three technical alternatives poses questions about how local distribution should be accomplished. Demographic characteristics of the region served will usually determine which system has the least cost. However, the best means of local distribution could be a combination of the competing technical arrangements.

Cost Characteristics for an Example Service

For the purposes of this discussion, an example service is taken from a teleconferencing study.* The service provides four channels for one-way video and two-way audio communications. The study, which reached the now familiar conclusion that satellite systems are often the most cost-effective way to provide long distance communications, provides cost estimates for earth stations, cable distribution, and an MDS-type system. Cost equations extracted from this report are used (with simplification) in this paper to provide order of magnitude estimates. The cost structure for a region with n users is:

earth station with cable access (C)

$$c = c_1 + c_2 n$$

rooftop earth stations (ES)

$$c = c_3 n$$

earth station with MDS system (MDS)

$$c = c_1 + c_4 + c_5 n$$

* Teleconferencing: Cost Optimization for Satellite and Ground Systems for Continuing Professional Education and Medical Services, D. Dunn, B. Lusignan, E. Parker, Stanford University, May 1972.

where:

c_1 = cost of earth station equipped for redistribution (11,500)

c_2 = cost per mile per user for cable distribution (6,000)

c_3 = rooftop earth station cost (9,200)

c_4 = cost of MDS transmitter (86,000)

c_5 = cost of user MDS receiver (8,600)

r = average mileage for cable distribution per user.

Figures in parentheses are approximate dollar costs for installed equipment and maintenance. Note that different types of systems may have different space segment designs for minimum cost operation.

C vs ES vs MDS

The minimum cost arrangements for regions described by the variables r and n are now examined. If only one technical arrangement can be used for a region, the transitions occur at:

ES-MDS tradeoff

$$n = \frac{c_1 + c_4}{c_3 - c_5} = 162.5 \text{ (receivers)}$$

C-MDS tradeoff

$$r = \frac{c_5}{c_2} + \frac{c_4}{c_2} \frac{1}{n} = 1.4\bar{3} + \frac{14.\bar{3}}{n} \text{ (miles)}$$

C-ES tradeoff

$$r = \frac{c_3}{c_2} - \frac{c_1}{c_2} \frac{1}{n} = 1.5\bar{3} - \frac{1.91\bar{6}}{n} \text{ (miles)}$$

The boundaries of these areas are plotted in Exhibits 1-A, B, C. Exhibit 1-D displays the composite of these boundaries. The C-MDS, C-ES, and ES-MDS boundaries intersect at a common point.

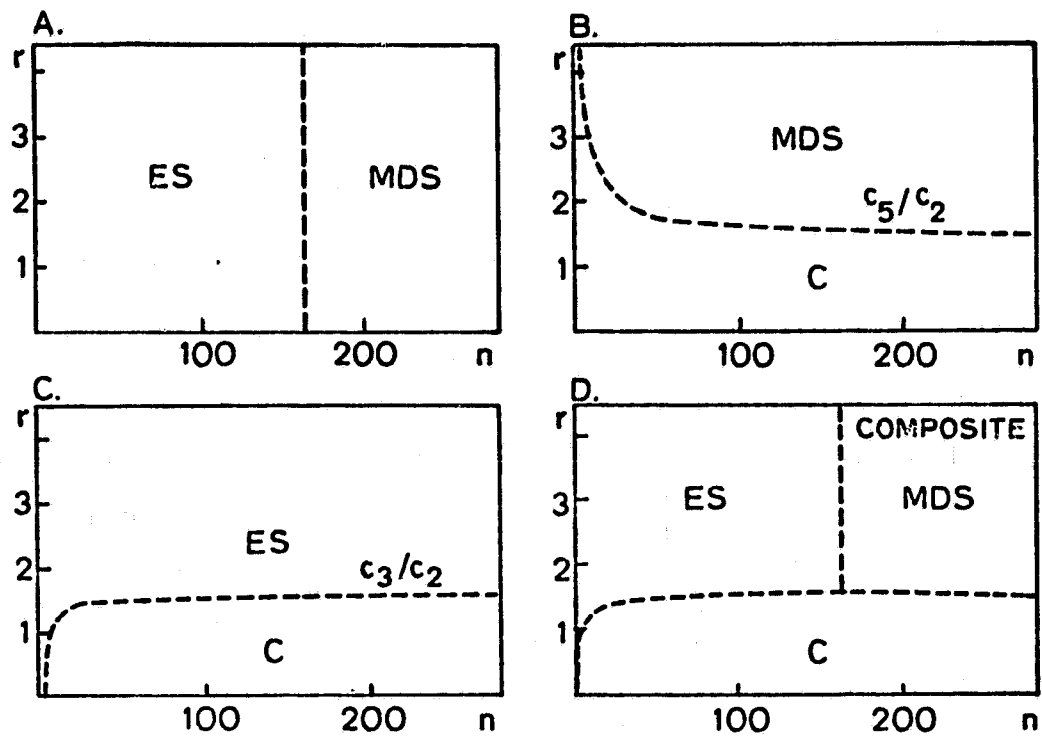


Exhibit 1

Using the above cost estimates, this intersection point is at $r = 1.522$ and $n = 162.5$.

The conclusion in this case is fairly straightforward. If the demand is highly concentrated, a central earth station accessed by cable is the lowest cost alternative, regardless of the number of users in the region. If the demand is low density (geographically dispersed), then either an MDS system or rooftop earth stations dominate in terms of cost. The choice between these latter two depends only on the number of users, provided users are not so widely dispersed as to be outside the range of the MDS transmitter. Higher demand favors the MDS system, since the incremental cost of an MDS receiver is slightly less than the cost of an individual earth station (an MDS distribution system has a fixed cost as well). However, if earth station costs become low enough, the MDS system will not be a least cost alternative in any region.

C vs C and ES

It is sometimes possible, when the space segment allows compatible designs of two local distribution technologies, to assume that more than one technology will be used in the same system. For example, consider the joint use of cable and rooftop earth stations. Given the cost characteristics of these systems, it seems that distribution cost would be minimized by employing cable for the nearby users and rooftop earth stations for the more remote users.

Unfortunately, the boundary separating near and remote areas is not well defined by r and n alone. More information about

the demography of the region is required. Specifically, we need to know the number of users n within a given radius r of the cable relay station. This information, which can be represented by a function of radius $n(r)$, is sufficient for us to obtain a second function, $r(n)$, which tells how average cable mileage changes as additional users are served.

For regions of interest, we will assume that all users can be ordered so that $s(n)$, the increment in cable-miles required to serve the n th user, is non-decreasing. This is a useful concept since it enables an evaluation of the incremental cost of serving the n th user by alternative arrangements. If served by cable, the incremental cost is $c_2 s(n)$. If served by rooftop earth station, the incremental cost is c_4 . This allows a division of users by the distribution technique serving them:

$$\text{Let } \bar{n} = \max \{n | s(n) \leq c_3/c_2\}$$

then use:

C for users $1, 2, \dots, \bar{n}$

ES for users $\bar{n} + 1, \bar{n} + 2, \dots, n$

Note that if $s(n)$ is not non-decreasing, a more complicated analysis is required. Furthermore, this analysis could indicate that a second central earth station accessed by cable is required to minimize distribution cost--a result that is precluded when $s(n)$ is non-decreasing.

It can be shown that $s(n)$ and $r(n)$ are related:

$$s(n) = r(n) + nr'(n) *$$

* The total number of cable-miles is $nr(n)$, the number of users multiplied by their average distance from the transmitter. The increment in cable-miles $s(n)$ is just the rate of change with respect to n of total cable-miles--the derivative of $s(n)$ with respect to n .

This relation can be used to plot an appropriate boundary for "C only" and "C and MDS" in our $r - n$ space diagrams for various assumed "demographies" $s(n)$. For example, suppose that regions of interest have users distributed such that $s(n)$ is linear:

$$s(n) = an \quad \text{for some constant } a,$$

so that $r(n) = \frac{an}{2}$ and $s(n) = 2r(n)$.

$$s(n) \text{ reaches the criterion } c_3/c_2 \text{ at } \bar{r} = \frac{c_3}{2c_2} \text{ and } \bar{n} = \frac{c_3}{ac_2}.$$

Note that for this special case, \bar{r} does not depend on n . This example is depicted in Exhibit 2-A. As shown, for any linear demography, there is a threshold value above which both cable and rooftop earth stations are used jointly. This threshold is one-half the value of the threshold (in the limit) in Exhibit 1-C.

To show that the boundary is not always flat, consider a logarithmic demography defined by:

$$s(n) = a(1 + \log n) \text{ for some constant } a$$

$$\text{so that } r(n) = a \log n.$$

$$s(n) \text{ reaches the criterion } c_3/c_2 \text{ at } \bar{n} = e^{1 + \frac{c_3}{ac_2}} \text{ and } \bar{r} = \frac{c_3}{c_2} - a.$$

$$\text{The resulting boundary is } \log n = \frac{rc_2}{c_3 - rc_2} \text{ or } n = \exp \left[\frac{rc_2}{c_3 - rc_2} \right].$$

This example is depicted in Exhibit 2-B.

It is important in the examples above to note that the boundary of the areas "C only" and "C and ES" is not invariant to the demographic "class" of the region. Even in the limit for a

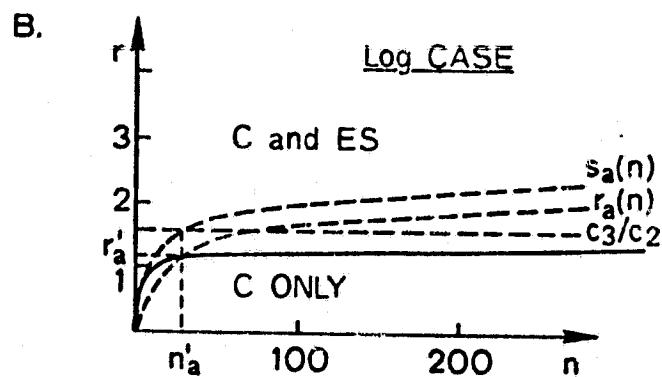
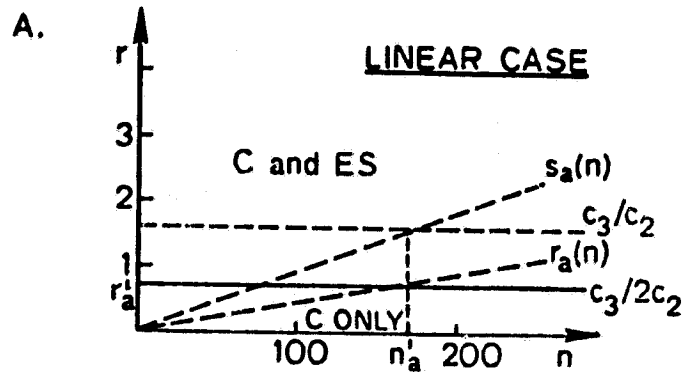


Exhibit 2

large number of users, the threshold for introduction of user earth stations depends on the type of demography assumed. For most regions of interest, the boundary is expected to be fairly flat as shown in the examples.

C vs C and MDS

Now consider the joint use of cable and an MDS system. This analysis proceeds parallel to the above analysis, except that it is slightly complicated by the presence of a fixed cost for the MDS transmitter. Otherwise, the MDS system has cost characteristics similar to rooftop earth stations. In the previous case, the behavior of $s(n)$ after it reaches the cost criterion was irrelevant as long as it was non-decreasing; in this case, it matters.

If the systems are used jointly, cable access will be employed for nearby users and MDS receivers for remote users. The users may be divided by the criterion:

$$\text{let } n^* = \max \{n | s(n) \leq c_5/c_2\}$$

then use

C for users 1, 2, ... n^*

MDS for users $n^* + 1, n^* + 2, \dots n$.

The system will be used jointly only if:

$$\text{Cost (C only)} > \text{Cost (C and MDS)}$$

or

$$c_1 + c_2 r n > c_1 + c_2 r (n^*) n^* + c_4 + c_5 (n - n^*)$$

or

$$n > \frac{c_4 + (c_2 r (n^*) - c_5) n^*}{c_2 r - c_5}$$

Consider again the linear demography $s(n) = an$ and $r(n) = \frac{an}{2}$. Transition occurs at $n^* = \frac{nc_5}{2rc_2}$ $r^* = \frac{c_5}{2c_2}$. The condition on n requires:

$$c_1 + c_2 rn > c_1 + c_2 \frac{c_5}{2c_2} \frac{n}{2r} \frac{c_5}{c_2} + c_4 + c_5 (n - \frac{nc_5}{2rc_2})$$

or

$$n > \frac{\frac{c_4}{c_2} r}{(r - \frac{c_5}{2c_2})^2} \left[\text{for } r > \frac{c_5}{2c_2} \right]$$

Exhibit 3-A displays the boundary for the linear demography. Note that this curve is always below the curve in Exhibit 1-B, which assumed that the systems could not be used jointly.

C vs C and ES vs C and MDS

Now let's consider the case where cable is used and either MDS or user earth stations can be used in addition. The linear demography $s(n) = an$, $r(n) = \frac{an}{2}$ is assumed again. To determine the boundary, note that:

$$\text{Cost (C and ES)} > \text{Cost (C and MDS)}$$

$$\Rightarrow c_1 + c_2 r(\bar{n})\bar{n} + c_3 (n - \bar{n}) > c_1 + c_2 r(n^*)n^* + c_4 + c_5 (n - n^*)$$

$$\Rightarrow c_2 \frac{c_3}{2c_2} \frac{nc_3}{2rc_2} + c_3 (n - \frac{nc_3}{2rc_2}) > c_4 + c_2 \frac{c_5}{2c_2} \frac{nc_5}{2rc_2} + c_5 (n - \frac{nc_5}{2rc_2})$$

$$\Rightarrow n > \frac{\frac{4rc_2 c_4}{c_5^2 - c_3^2} + 4rc_2 (c_3 - c_5)}{c_5 - c_3}$$

$$\text{In the limit on } r, \quad n = \frac{c_4}{c_3 - c_5} = 143$$

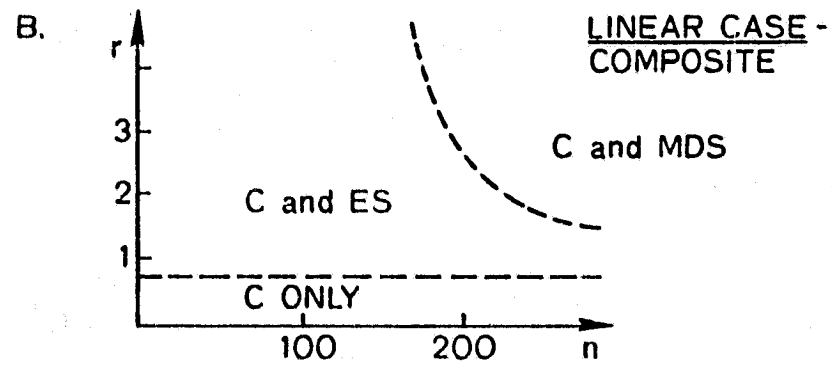
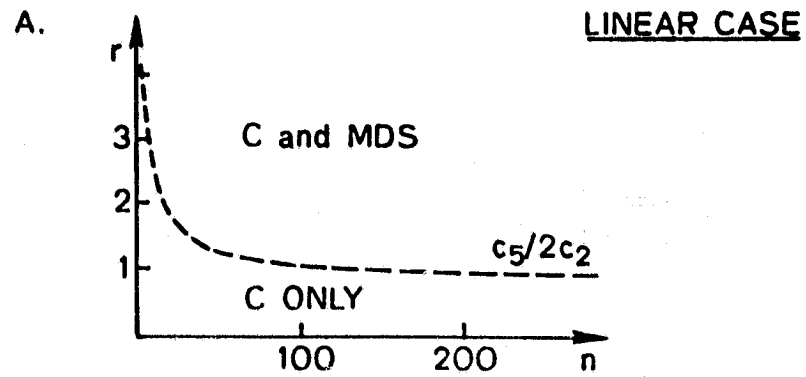


Exhibit 3

Note that the fixed cost for a central earth station does not enter in the boundary relation since both systems require it. This result is depicted in Exhibit 3-B, and represents the composite boundaries for the linear demography. Compare this figure to Exhibit 1-D, where it was assumed that only one system could be used in a region.

Remarks

In this paper, a technique has been described that can be used to determine the demographic characteristics of regions which favor different technical arrangements for local distribution of satellite traffic. The example used finds the least cost arrangement to be a central earth station with cable access for medium to high density areas of a region, combined with rooftop earth stations or MDS for more remote users in the region. The rooftop earth station--MDS tradeoff is decided principally by volume, with the latter arrangement preferred for high volumes. More analysis is required to support this finding for more general demographies.

**THE ECONOMIC BASIS FOR NATIONAL
SCIENCE AND TECHNOLOGY POLICY**

by

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National Aeronautics and Space Administration

Contract NASW 3204

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Report No. 23

PROGRAM IN INFORMATION POLICY

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Abstract

This paper is concerned with national policy issues that arise with respect to science and technology. The creation, dissemination, and use of science and technology in society can be viewed as an information activity. The management of this activity is the subject of science and technology policy. Two categories of policy instruments are discussed: (1) market-oriented approaches; and (2) direct public action. This paper is primarily concerned with pointing out possibilities for increased use of market-oriented approaches that can provide benefits to society in the form of an increased rate of innovation and of more "appropriate" technology, better suited to the needs of users.

1.0 INTRODUCTION

National science and technology policy is concerned with societal choices with respect to technological change and the adoption and use of new technology in society. The creation of new technology can be viewed as the creation of new knowledge or information through research and invention. Invention and research, in turn, draw on previous work, and a society's policies with respect to the storage, retrieval, and dissemination of scientific and technical information are important elements of national science and technology policy. The adoption and use of new technology in society can be influenced in many ways by government policies and actions. Many policies that affect the use of new technology involve questions of access to or the provision of information concerning the new technology to users. This paper is concerned with all three stages of the information production-consumption process in the science and technology field: creation, dissemination, and use. While it may seem restrictive to focus on the information-related aspects of science and technology policy, a policy such as a ban on the sale of a particular product is usually based on information concerning the use of the product and also is ordinarily adopted because the existing system of information dissemination to users is deemed inadequate. Thus, in most situations, an information focus captures the essential features of policy decisions.

A government agency, such as NASA, is involved with all three stages of the information production and consumption process in its own field of space science and technology. It creates new information through its research and development programs. It disseminates this information and

assists nonaerospace firms and various government agencies in making use of this information through its technology transfer program. And NASA is also, of course, a user of both NASA-created and other information in its own research and development programs. A private sector firm is also typically involved in all stages of this process in its own field of activity.

The objectives of national science and technology policy have traditionally been thought of in terms of increasing economic efficiency, productivity, and GNP. These overall national economic objectives can each be affected by changes in policy with respect to creation, dissemination, and use of scientific and technological information, and a number of these connections will be discussed here.

Efficiency, productivity, and GNP are all quantities that are independent of what is being produced. By focusing on these economic measures it is implicitly assumed that the national output is produced in properly functioning markets, in which the goods and services that are preferred by consumers are being provided. Of course, only a portion of the national output is produced in properly functioning markets in the U.S. or any other country. If only a small fraction of the GNP is produced outside of properly functioning markets, the effects of ignoring the nonmarket sectors in developing science and technology policy may not be serious. However, the U.S. economy has become a non-market economy in many of its major sectors, and it is doubtful if these sectors can be ignored in future planning. Several types of deviations from a market economy exist, and some of their implications for science and technology policy will be discussed. Some of these deviations are

often referred to as market failures. Those of special interest here are: (1) monopoly; (2) government regulation; (3) government provision of services; and (4) the fact that the principal costs of provision of service are being incurred by users rather than providers. As a result of these deviations and market failures, the validity of focusing primarily on productivity and GNP when seeking to formulate national science and technology policy becomes doubtful. An attempt is made here to suggest some more relevant measures of economic performance, but these suggestions can only be viewed as preliminary at this stage.

The growth rate of productivity has been decreasing in the 1970's in the U.S., while this quantity, along with the real GNP, has continued to increase in Japan, West Germany, and some other nations [1]. Economic (GNP) growth in the U.S. has been primarily a result of an increase in productivity and only in small measure a result of capital investment [2], [3]. The factors that influence productivity are therefore of considerable interest. The entire subject is confused by the use of noncomparable measures and by the aggregation of sectors of the economy, such as manufacturing and services, that may have widely different rates of change of productivity. However, in the period 1900-1960 steady productivity increases in both manufacturing and agriculture occurred. Denison has put forward the hypothesis that, since schooling increased in the U.S. during these years of productivity increase, schooling was responsible for the increase [4]. A more persuasive argument put forward by Klein is that productivity increased as a result of innovation in dynamically changing competitive U.S.

markets [5]. Klein's argument is that the U.S. market is now less competitive and that, since firms feel less pressure to innovate, there is less innovation and consequently a reduced rate of increase in productivity. Causes of the decline in competitive markets can be found in the increased roles in the economy of industries subject to regulation, industries with highly concentrated market structures, and governmental provision of services.

In addition, it has been widely observed that the U.S. is now an "information economy," in the sense that more than half of our paid workers and our economy is now engaged in the production of information-related products or services [6], [7], [8]. Information is not like other economic goods, because new ideas can be copied, usually at a much lower cost than the cost of creation. Therefore, the cost of creation of a new idea, through investment in basic research, for example, may not be appropriable, and potential investors will tend to underinvest in basic research for this reason. When we speak of underinvestment in this connection, we mean, relative to the amount of investment that would be socially optimal. Society receives benefits that go beyond the benefits received by the consumers of education and the firms that do basic research. It is therefore in society's interest to intervene in the markets for innovation, information creation, and education through government subsidies or by creating incentives for enhanced investment in these activities in the private sector. Various governmental actions have been taken to make investment in innovation more attractive, including patent, copyright, and tax incentives. Direct public support of basic research and education is also

a traditional part of national science and technology policy. It is not at all clear that reliance on these traditional policies will be the most effective national policy in the years to come.

Perhaps the most significant deviation from a market economy in the U.S. is a result of the existence of the "household economy" in which the final output of the market economy is combined with user time to produce the services that users ultimately consume [9], [10]. The existence of the household economy is not a form of market failure, but its existence raises a question, familiar in system analysis, of possible suboptimization through a focus on the market economy portion of the total system, rather than on the total system which includes both the market economy and the household economy. If the household economy were small in comparison with the market economy, a policy focus on the market economy might be justified. However, in the U.S., the household economy is comparable to the size of the market economy [9]. Therefore, it may turn out to be very important to consider the effects of science and technology policy on the household economy along with its effects on the market economy.

2.0 THE PRODUCTION AND CONSUMPTION OF SCIENTIFIC AND TECHNOLOGICAL INFORMATION

The information production-consumption process can be thought of as beginning with the creation of new information and proceeding through a dissemination process to the user who then consumes the information or uses it, possibly in creating a further innovation. An innovation that is brought to the market often includes both a new technology and a new concept of how this new technology can be utilized. Innovations

often create new information that is disseminated and incorporated in other new products or services, etc.

There are three main policy instruments that have been used to encourage individuals and firms to create, disseminate, and utilize new information: (1) patents and copyrights; (2) direct funding of research, development, and production by the government; and (3) subsidizing and other facilitating private sector investment in innovation and related activities. These policy instruments will be discussed in the following.

2.1 Patents and Copyrights

When we think of the individual inventor or creator of a new work of art, it is easy to see the economic effects of granting a patent or copyright to this individual. The patented invention or copyrighted work is protected against copying for some period of years and is thus made more valuable and more readily sold, and this increased value creates an incentive for further investing in innovation and invention.

There is an apparent tension between the policy objectives of obtaining a high national level of creativity and the policy objective of obtaining rapid dissemination of the results of the creative process. The policy instruments, such as copyright laws, that have been used to encourage creativity do so by creating barriers to copying and apparently act as obstacles to rapid dissemination. However, the tension is primarily a tension between short and long run objectives. In the short run, an innovation can perhaps be most rapidly disseminated by allowing free access to it. But in the long run, it is

necessary to be concerned not only with dissemination of known ideas, but also with the continued creation of new ideas, so there will be something to disseminate. Patents and copyrights encourage both innovation and the disclosure of innovation. The alternative of allowing free dissemination results in innovations being kept secret as far as possible, which obviously does not promote dissemination. Even under a property right system, many innovations, such as computer software, are not protected, and innovators often go to considerable lengths to keep their ideas secret [11], [12].

The effects of patent laws on the operation of a modern, competitive industrial market can be rather different from the effects on individual inventors. In modern industry, the invention process has been commercialized. Inventors are hired and organized to create new ideas that will be most beneficial to the firms that employ them. In some markets the innovation process has been accelerated to a very high pace. The computer industry is an example of an industry with a rapid development cycle, typically less than 5 years for a major innovation. A rapid obsolescence of products naturally accompanies this rapid introduction of new products. Five-year old computers may work very well, but their value is only a small fraction of their purchase price.

An important distinction needs to be made between the invention process that may be involved in creating a new product and the innovation process that is concerned with selecting the specific characteristics and technology of the new product and bringing it to the marketplace. Many innovations are not patentable. But innovation is protected

by trade secret law and by the time it takes to copy a new product. In a high technology field, the time to copy may be over a year, and a firm that is a year or two behind its competitors may find that its competitors have written off the costs of creation by the time its product reaches the market, so it does not gain a price advantage through copying. In such a market, copying would not be a successful strategy. The role of patents in such a market is unclear. Patents on basic inventions that will be used in several cycles of innovation have long-term value. Patents on obsolete products are obviously not of value. The usual argument that firms will underinvest in innovation does not seem to apply to rapidly changing, high technology markets. Firms in these markets must innovate in order to survive. Firms can effectively nullify the effects of patents by entering into cross-licensing agreements. Firms, in effect, give up the potential rewards from occasional basic patents in order to avoid the risk of competitors' inventions blocking their access to the market. Of course, cross-licensing and patent pools can violate the antitrust laws [13]. But if all new entrants to an industry can join the licensing agreements, the effects are not anticompetitive.

The economics of invention and innovation in markets with rapidly changing technology appears to be an important field for research [14]. Neither the operation of such markets without government intervention nor the effects of patents and cross-licensing agreements in such markets are now well understood.

2.2 Direct Funding of the Creation of New Information

As an alternative to creating property rights in new information through patents and copyrights, direct public investment can be made in the creation of new information. In areas in which the government has a mission responsibility, as in defense and space, it can be expected to support the research that it believes will be most beneficial to its missions in the long run. In areas in which the private sector is responsible for providing products and services to consumers, there is also a potential role for government supported research, especially basic research. The economic argument that firms will underinvest in research that leads to inventions subject to copying is even more applicable to basic research that is aimed at understanding nature, because patents do not cover theories or laws of nature. Thus, the discoveries that come from basic research will benefit a firm's competitors as much as the firm itself (except for public relations benefits), so the amount of basic research done in the private sector will tend to be less than is socially optimal [15], [16]. Some form of governmental intervention in the market, in order to create increased incentives for carrying out basic research, is therefore appropriate. And direct government funding is a straightforward way to support basic research.

Once government funding of research is adopted as a national policy, a question arises with respect to the ownership of patents and copyrights on innovations made in this research. Presumably, the national interest is best served by a government patent policy that will maximize innovation. Government ownership of patents results in

disclosure, but it does not create incentives for firms to make the necessary investments to bring these patented innovations to the market. Granting of exclusive rights to firms that do make such investments would enhance the incentives to develop these innovations, much as homestead rights have been used to encourage the development of government land.

Another important policy issue in this area is that of the allocation of funds. What areas of research should receive funding, and at what levels? A balance of many diverse interests is somehow achieved in the present system. However, there may be opportunities for improving the present system, for example, by creating more independent sources of research funding that are likely to support research leading in new directions. Both industry and mission-oriented agencies could strengthen their positions in the long term by supporting basic research projects of special interest to them, rather than relying on others to provide this support.

2.3 Facilitating Private Sector Investment in the Creation of New Information

Industrial investment in research can be increased through tax incentives. However, there is the risk that the amount of new research may be small in relation to the amount of tax subsidy, because firms have an incentive to reclassify existing activities to qualify for favorable tax treatment as well as to initiate new research.

Also of importance is the possibility of more industry-sponsored research, on an industry-wide basis, in universities, industrial research labs, or research institutes. There are likely to be many

cases arising in the future in which it is important for an entire industry to develop a new set of techniques that will be used throughout the industry. Projects to develop these techniques could appropriately be funded and managed by the concerned industries themselves, without governmental intervention. Industry cooperation in such research programs could, however, have antitrust implications, and it is possible that new legislation would be helpful in encouraging this type of industry-wide research activity.

The principal limitation on industry-wide research is the competitive nature of industrial firms and the desire by each firm for secrecy and the exclusive use of new ideas created by an individual firm. However, there are precedents for this sort of industry cooperation in many industries. The necessary condition for a successful program of this type is a guarantee of access to all outputs of the program to all industrial participants in the program. This condition can best be met by carrying out the research in universities or non-profit institutions, separate to some extent from the firms. It would be difficult to create a successful program that would employ scientists and engineers from the participating firms in the direct conduct of the cooperative research. On the other hand, from a national policy standpoint, a central feature of this approach would be the participation of scientists and design and development engineers from industry in project selection and the directions to be taken in the research done under the program. The incentive for firms to provide this costly participation in the management of the research program would be stronger under an industry-financed program than a tax-supported program.

2.4 Facilitating Private Sector Innovation

The production-use cycle can be entered at the use end rather than the creation end. Policy instruments can be designed to facilitate the use of existing information in the process of bringing a new product or service to the market, i.e. in the innovation and product planning process. NASA's technology transfer program is designed to assist government agencies and industrial firms in the nonaerospace sectors of the economy in making use of new technology that has been created in the space program and that has promise for utilization in other sectors of the economy.

The policy instruments used by NASA include: (1) creating information "bulletins" or abstracts that describe the new technologies believed to have significant potential in nonaerospace applications and making these abstracts readily available to U.S. industry and government agencies; (2) assisting nonaerospace users in the product planning process, for example by going beyond an information abstract to a complete business plan for the adaptation of a NASA-developed technology to a specific commercial application. This latter form of technology transfer obviously requires careful project selection, because there may be hundreds of possible products or services that could be developed from a specific NASA technology. However, it has the important value that it creates an example that is specific enough to present potential users with a much more complete picture of the possibilities than a simple description of the technology itself. Even if the sample business plan is not adopted, it could stimulate a user to create a business plan that would be adopted. The

technology transfer process is not well understood, but it seems reasonable that it might be economically efficient to go somewhat beyond the basic abstract and document dissemination process. What is unclear is just how far and in what ways it is efficient for an agency like NASA to enter into the product planning process.

A somewhat different approach to technology transfer is to provide a subsidy to firms willing to undertake product planning and development of products that would use certain classes of technologies or that would provide products or services of certain desired types. Both Japan and England have experimented with this approach, using a "national research and development corporation" as the organizational entity for carrying out this idea. Rep. Fuqua has introduced a bill that would create a U.S. quasi-governmental corporation to encourage the development of new products, processes, and industries using the properties of the space environment [17]. The bill provides for the "space industrialization corporation" to provide funds to industrial ventures under negotiated management plans, with repayment including a profit being required of profitable ventures. This provision follows the plan of British and Japanese corporations that have been organized in the same way with repayment only required from profitable ventures. It also incorporates the important concept of allowing negotiation rather than requiring competitive bids. A sum of \$50 million per year for two years is proposed to get the corporation started. Further funding could be voted. The Fuqua plan creates a corporation that would initially be an agency of the federal government, but provides that it can be converted into a publicly owned private corporation.

A significant advantage of this approach to technology transfer is that it would leave the entire product planning process to industry, where it can be done best, and it does so in a way that protects the confidentiality of the ideas submitted in proposals. The research and development corporation would not be required to use the competitive bid approach and hence would not have to define the product or otherwise inject itself into the product planning process. It would only have to select which proposals to support. If it maintained confidentiality of the proposals submitted, it could expect to receive proposals with the best available innovative concepts that industry could present. The economic justification for this approach in a market such as the industrialization of space is the uncertainty of profits, combined with very large investment per project required, in a market that would offer long term benefits to the U.S. by maintaining the comparative advantage the U.S. has developed in space technology and applications. There is no reason that this approach could not be used for "market development" programs in a wide variety of fields.

3.0 IMPROVING THE OPERATION OF MARKETS IN ORDER TO ENCOURAGE INNOVATION THAT IS RESPONSIVE TO CONSUMER DEMAND

It has become apparent in recent years that industries with a high degree of concentration, with strong local monopolies, or with high barriers to entry more often than not achieve their protection from competition through government action [18]. Industries that consist of a few large firms seem to have less incentive to innovate, if it is difficult for small competitors to enter their market with innovative

new products. In industries where small competitors can enter the market rather easily, as in the computer industry, small firms provide a very large fraction of the innovation that occurs.

Four major types of policy options are considered here that are of interest in dealing with industries that have somehow managed to obtain governmental protection from competition: (1) deregulation in "regulated industries" such as railroads; (2) deregulation in "unregulated" markets; (3) improved consumer information in all markets, but especially in local service markets; and (4) privatization of markets dominated by government providers of service.

3.1 Deregulation of "regulated industries"

Although government regulation is often adopted as a consumer protection measure, the eventual effect is usually to limit competition by creating barriers to entry to the regulated market [19]. The pace of technological change in regulated markets is slowed for a number of reasons. Governmental approval may be required to make new investments of certain types, and the regulatory process can be used to prevent an innovative firm in a regulated market from introducing new technology as fast as it would like. Once new technology is in place, the regulatory process can be used to prevent pricing services that use the technology in ways that would threaten less innovative service providers. In addition, regulators and regulated industries may adopt pricing strategies that minimize present prices but slow the introduction of new technology that would reduce prices in the future. Only in markets where competition is restrained by government action can these anti-innovation policies be pursued and sustained for long periods of time.

A government can, thus, through its own actions, create a competitive disadvantage for its industries in world markets. Of course, governments do not act to regulate an industry without the consent of the industry, and usually governments are pushed into regulation by industry, in order to limit competition [20]. However, when new national policies to encourage innovation are being considered, it is difficult to think of a more significant policy option than deregulation, in industries presently subject to regulation [21].

This argument does not depend on economic studies of innovation as a function of firm size or market structure. A number of studies have been made of the various economic characteristics of firms, in an attempt to identify market conditions favorable to innovation. It has been suggested that large firms may be more apt to innovate than small firms, because they have more flexible resources [22]. Firms in competitive markets that are not too fragmented have been found to be more innovative than firms in either highly concentrated markets or markets with a large number of very small firms [23]. However, the rate of innovation is also strongly a function of the specific industry and its stage of evolution [24]. Regulation could be used to influence firm size or market structure, but its direct effects on innovation are, in the author's opinion, much stronger than any of the other market characteristics that have been studied. And the evidence is that regulation is consistently used to slow the pace of innovation. For example, the rate of innovation in the business telephone terminal market was extremely slow when this market was protected from competition. The Carterfone decision in 1968 opened this market to competition, and

there has been a high rate of innovation since that date, both by AT&T and its new competitors [25], [26]. The opportunity exists to increase innovation through deregulation in many other U.S. industries.

Deregulation would not only tend to benefit consumers through an increase in the availability of new products and services, but also through reduced prices for existing services resulting from process innovation. Perhaps equally important in the long term would be the improved position of the U.S. in world markets in the deregulated industries. In many cases regulated industries in the U.S. are industries that are completely governmentally managed in other countries, such as railroads, telephones, and broadcasting. Thus, even though technological change in these industries has been limited by regulation in the U.S., it has also been slowed in other countries by even more constraining governmental action. Therefore, the U.S. is not yet at a competitive disadvantage in most of these areas. And the opportunity to take or maintain the lead in these areas is still open.

As these markets are deregulated and start to admit innovation at an increased rate, foreign equipment suppliers will be attracted to these markets along with U.S. suppliers. Pressures will then undoubtedly develop to protect U.S. equipment suppliers from foreign competition. Protectionism in these markets will be more easily justified, if foreign markets of the same types are not open to U.S. industry, as is almost certainly going to be the case initially. In the long term, however, international competition may cause deregulation worldwide, if it is initiated by the U.S. and if deregulation does lead to more rapid technological change. A more rapid rate of technological change in the

U.S. and an improvement in the relative position of U.S. firms in these industries relative to foreign firms may create pressure for deregulation worldwide as a competitive response.

The trend toward more rapid diffusion of innovation throughout unregulated world markets has been widely noted. Lower wage costs in developing countries make them competitive sources of manufactured goods, thus putting more pressure on the developed countries to increase the pace of innovation. At the same time, the growing world markets are making it easier to write off R&D expenses and to finance innovation. The deregulation of U.S. regulated markets would simply be another step in this process.

3.2 Deregulation in "unregulated" markets

Many industries that are not regulated in the sense that public utilities are regulated are nevertheless neither competitive nor innovative. Usually these industries are highly concentrated and the role of government in these industries is often anticompetitive, even though less obviously so than in the case of public utilities.

For example, in the drug industry the government plays a complex role. In connection with prescription drugs, advertising of prices and the introduction of generic drugs would obviously increase competition. The high cost of testing new drugs creates a barrier to entry by new smaller firms. Government policies aimed at increasing competition could encourage innovation in this industry.

The broadcasting industry plays a key role in the economy. It is not regulated in the way that public utilities are regulated. A market

in broadcast stations exists; entry is possible through purchase of an existing station. But government plays a central role in limiting competition and the operation of the market in this industry [20]. For example, pay-by-program television has been technically feasible since the late 1950's. But the introduction of pay television into the broadcast market would create economic risks for the existing networks and stations. Their markets have been protected from pay television competition up to the present time by restrictive FCC rules and the administration of those rules, even though it makes no more economic sense to ban pay television than it would to prevent magazines from charging consumers for copies and allow only magazines that relied exclusively on advertising for their revenues to exist.

There are many opportunities to increase competition and innovation in unregulated U.S. industries, simply by withdrawing governmental support for anticompetitive practices in these industries. Thus, the science and technology policy option of greatest significance in many industries today is simply the option of repealing previous legislation. This statement has many detailed implications that differ from industry to industry. And each industry would require a major study and analysis effort, as well as a political consensus sufficient to overcome industry opposition to deregulation, in order to implement a deregulation policy option. That such an option is worth considering has been demonstrated by airline deregulation.

3.3 Consumer Information

A well functioning market requires that consumers have adequate information about price and quality. Otherwise, competition cannot exist. Yet, in many consumer markets, the consumer not only has inadequate knowledge of product quality, but also has difficulty obtaining even price information. Most advertising is not intended to provide this type of information, but rather to inform consumers of the existence of products, sources of services and products, and to create favorable impressions of the advertised product or service. While Consumers Union provides comparative information of the type that consumers need on nationally advertised products, very little information is available on the local services and products that consume most of the consumer's income: housing, medical services, auto repair service, and other local services.

It is not reasonable to expect either government or industry to provide the type of information that consumers need. The job will almost certainly have to be done by consumer groups, if it is to be done at all. Nevertheless, the opportunity exists for government to facilitate the development of consumer information services. It is reasonable to expect very substantial gains in the productivity of local services, as well as a much more rapid rate of innovation in these industries, as a result of increased competition that would result from improved consumer information at the local level [27], [28].

3.4 Privatization

In many sectors of the economy the government acts as a monopoly or near-monopoly provider of services. The postal service, the public

schools, public libraries, defense, and the exploration of space are some of the major markets dominated by government or quasi-government providers. One of the sources of difficulty in these markets is the fact that services are provided to users at zero price. Funds are obtained for the provision of these services through general taxation, and these funds are allocated to the service provider by Congress or a state legislature. Such organizations become attuned to the wishes of their legislative constituents, but their incentives to serve their users are weak and exist only to the extent that their users make their demands felt by their representatives in the legislature. In some cases, this system is quite satisfactory. When the users are industrial firms, the likelihood is high that the legislature will adequately represent the interests of the user in dealings with the government service provider. However, when users are individuals, it is difficult for the users to arrange for their interests to be adequately represented. A policy option that is, in principle, easy to adopt is to charge users directly for the service, rather than to use tax funds to pay for the service. The principal benefit of this approach is that service providers become more attentive to their customers. However, this approach does not benefit users to the full extent possible unless users have an alternative supplier to turn to. Thus, the postal service feels some pressure from the threat that users will reduce their purchases of service, but the pressure is much greater, if users can get their packages or messages delivered by an alternative service provider such as United Parcel Service. Thus, the combination of funding through direct user payments with opening

the market to competitors avoids the principal difficulties with government provision of service. But there is still one difficulty with such a market, and that is the fact that both government and private sector monopoly service providers tend not to price their services in proportion to cost. In other words, they subsidize one service from revenues obtained from another service. Such cross-subsidies are often introduced in response to their legislative constituents [29]. Once in existence, such cross-subsidies are politically difficult to eliminate, and their existence can block the adoption of open entry policies that threaten to force the market toward cost-based pricing. An example is the subsidy of rural mail delivery by urban mail. The only satisfactory way of preserving such subsidies is to make them into direct subsidies. However, direct subsidies are more difficult to get political support for; their economic and social effects are often examined more closely than are the effects of indirect subsidies. For example, should rural mail and telephone subsidies be extended to both rich and poor rural dwellers, and, if not, how could the distinction be made on a practical basis?

If a direct subsidy is acceptable politically, as it might be in the case of low income users of public schools and libraries, it can be combined with a direct user payment system by providing vouchers to the low income users [30]. But again, such a system is only fully effective if the user can turn to an alternate source of service if unsatisfied. Once free entry is allowed, along with cost-based pricing and direct user payment, the need for a government service provider often disappears altogether. The only residual trace of

government intervention would then be the provision of vouchers or scholarships to low income individuals. In such a case, full "privatization" of the service can be accomplished.

In defense and space, the path to privatization is not as straightforward as it is in the case of purely domestic services. Nevertheless, in both defense and space in the U.S., the government relies on the private sector for its hardware, software, and some of its operational services, so some elements of privatization are present in these services. The opportunity for further privatization may exist in defense and space, and analysis of this possibly appears to be appropriate. The directions in which innovation in these fields is moving is now determined by a process in which the individual consumer plays almost no role whatsoever. It is not easy to bring the consumer into these fields effectively. A token, uninformed consumer on an advisory board is not an effective mechanism for getting consumer "input." One possibility that has not been adequately explored is the idea of improving consumer-oriented information about the operation and significance of these agencies. Of course, both agencies now spend substantial sums on providing information to consumers, but this information is organized and presented in a way that is likely to strengthen public support for existing programs. The new possibility is to provide information that will cause consumers to question the basic premises and orientation of existing programs and to see some of the options for defense and space that are not now given official support. It is quite possible that a more open, questioning approach to defense and space policy would result in more innovation and more effective programs in the long term.

4.0 IMPROVING THE MANAGEMENT OF GOVERNMENT SPONSORED RESEARCH AND DEVELOPMENT

The market concepts discussed in previous sections have some bearing on the questions of the appropriateness of government sponsorship of R&D and of how project selection in government sponsored R&D should be carried out.

Starting with basic research, there seems to be little controversy over the appropriateness of some form of governmental stimulus to this activity, whether through direct support, patent and copyright protection, or tax incentives. The project selection mechanism is now fairly diverse, and there are many reasons for favoring a diversity-oriented approach to funding and project selection. The economic concept that is relevant here is that the customers or users of basic research should be involved in project selection and funding, by analogy to the role of the consumer in markets. This concept is only occasionally operative today. A possible example of the application of this principle would be to bring product development engineers into the project selection process in the support of research projects in their field at an agency like NSF. This group now influences, to some extent, the paths of basic research within their own companies. It might be feasible to increase their influence in government sponsored programs as well, on the basis that they are the most direct consumers of basic research. The ordinary individual is the ultimate consumer of basic research, and again the only realistic opportunity for increasing consumer participation appears to be through improved consumer information on the basic research establishment and its operation.

Considering next the role of government in relation to applied research and development, the appropriate role is fairly clear in areas in which the government has a mission responsibility and monopoly, such as defense and space. In these areas the government is responsible for funding, project selection, and overall management. The possibility of increasing the degree of privatization and through this, competition and innovation, was discussed above. In civilian markets, there may also be a role for government sponsored applied research and development, but the case is less clear. If there is an appropriate role for government sponsored R&D in civilian markets, it is probably primarily in applied research, because product development is closely tied to the market and is best done by firms that are familiar with the market [31].

Applied research is research that is oriented toward specific applications in specific markets. It is often clear that a specific type of device or technique is of key importance in the evolution of a particular field, and it is clear that the best way to promote progress in this field is through the development of specific devices or examples of the critical technique. In such cases this development is not coupled directly to the market, but rather represents learning work that goes beyond basic research and prepares the way for market-oriented development to follow. An example might be a key component in a large system, such as a new type of communication satellite that would make possible an improved communication system. In such cases, there may well be a case for government sponsorship of R&D on the economic grounds that the private sector tends to underinvest in this

type of work, because it is unable to appropriate the results. A firm is likely to underinvest in applied research that could benefit its competitors as much as itself; it will prefer to wait until there is a specific market opportunity to focus its work on. Thus, if the government can find these critical areas of applied research, it can probably make an important contribution to the national competitive position in whatever industries it chooses to support.

The process by which areas of government applied research are chosen is thus an important element of the R&D program. It may be that there are opportunities for organizational improvements in the project selection process. At the present time, U.S. government agencies have advisory panels that help them to keep in touch with the industry and its views. A possible opportunity for improvement might lie in the way industry representatives are chosen for these panels or in the ways that panel members are able to express their views. In some cases an industry panelist may know of an area that would be productive for government R&D, but may be reluctant to share his ideas with his competitors. There may be an organizational alternative that would allow secrecy to be maintained. For example, if the R&D is government sponsored but done in industry, a negotiated contract rather than a competitive procurement could protect the ideas of the industry R&D group. Of course, this approach would violate many of the existing constraints on government contracting. An alternative to this approach is the creation of tax incentives for firms to do R&D that allow firms to make project selections completely on their own [31]. The weakness of this approach is that it results in the

support of a great deal of work that industry defines as R&D for tax purposes, but that may be nothing more than restyling, as in the automobile industry.

One way of looking at government R&D in civilian markets is that the government is acting as an industry-wide cooperative R&D agency. A portion of the industry's corporate income tax can be thought of as being allocated to this purpose, and it is therefore reasonable to expect R&D project selection to be made by industry. In order to avoid the weaknesses of both government sponsored R&D and the tax incentive approach, it might be possible to encourage the development of industry-wide R&D activities outside of government, as discussed in Section 2.3. The "national research and development corporation" concept discussed in Section 2.4 is another option that allows greater confidentiality than a government sponsored program with consequent increased flexibility and potential for innovation.

5.0 INCREASING "APPROPRIATE" INNOVATION IN LARGE-SCALE SYSTEMS

Starting with Jacques Ellul [32], there has been a steady flow of literature concerned with the uncontrolled, apparently autonomous evolution of technology in directions that are "inappropriate" because they are not directions that benefit consumers [33], [34]. The principal contribution of economic theory to this question is to suggest that these "inappropriate" evolutionary trends in technology are most likely to occur in sectors of the economy in which market forces are ineffective, often as a result of governmental action. For example, the choice of new technology in U.S. hospitals is not limited by considerations of economic

efficiency, because insurance payment systems cover all costs and there is no effective competition in this market. The result has been an extraordinary rise in hospital costs [35].

System analysis can contribute to an understanding of these trends by pointing to examples of inappropriate technology in areas in which large-scale societal systems are being built with inadequate coordination and planning, such that "suboptimization" is taking place. The subsystems of these inappropriate systems are being optimized, but no one is looking after the overall system optimization. For example, in attempts to increase productivity in post-secondary education, televised classes have been used to increase the number of students per teacher. Television and other educational technologies such as audio cassettes used in combination with still visuals have been found to have no significant difference from each other and from live classes. When optimization of the school's operation through minimization of teaching costs is done, television appears to be the preferred technology. However, if optimization of the entire learning operation, including the cost of student time, is done, technologies such as audio cassettes (videorecording technology is still too expensive for most students) that offer students the chance to listen to lectures when they wish and to review them as often as they wish, result in lower total costs. The optimization of the school's productivity is a suboptimization, because it fails to include the entire system and the costs of student time that would be included in an overall system optimization. The system boundary in such a case has been incorrectly drawn, from the standpoint of society, even though correctly drawn from the standpoint of the school.

A similar suboptimization is taking place in some areas of national

science and technology policy. Present policy focuses on productivity in the market economy and on GNP, the output of the market economy rather than on the output of the total economy. The total economy includes both the market economy and the household economy. In the U.S., the household economy is comparable to the size of the market economy, because for most services that consumers receive, the cost of consumer time is several times as large as the price that users pay into the market economy for goods and services [9], [10]. As in the case of educational technology, there is a danger that firms will choose the best technology from their standpoint and end up with the wrong technology from society's standpoint. Wrong choices by firms will be corrected in markets where users have a chance to obtain services from more than one provider. However, in fields such as education, medical care, defense, and space, where there are local or national monopolies, wrong choices are not automatically corrected.

One approach to science and technology policy that would improve technological choices in large-scale systems is, of course, to improve the operation of markets by increasing competition and consumer choice, as discussed in Section 3. When deregulation and competition are not feasible, it still may be possible to refocus technological choice toward options that will minimize total cost rather than provider cost and that will optimize total system operation rather than the subsystem under the control of the provider. Any new non-market approach to science and technology policy that seeks to induce overall system optimization will probably have to do so by facilitating large-scale system planning that does in fact take users into account in the organizational design.

For example, there are many opportunities for innovation in such areas

as city design, in the organizational sense rather than the physical sense. In principle, such local service markets as housing, transportation, education, and police services could be highly innovative. Their organizational design is presently highly constrained by regulation and most are monopolistic. Both market incentive approaches, such as deregulation and privatization, and new organizational designs that encourage overall system optimization could usefully be the subject of analysis and R&D.

6.0 CONCLUSIONS

Science and technology policy is concerned with the rate and directions of technological change in society. Two broad categories of policy instruments are available: (1) market-oriented approaches, such as the modification of property rights in newly created information through patent law, that seek to increase the incentives for the private sector to invest in R&D; (2) direct public action, such as government sponsorship of R&D, that seeks to substitute government action for the operation of the market. Much existing policy makes use of the direct action approach. This paper has been primarily concerned with pointing out possibilities for the use of market-oriented approaches and some of the advantages of such approaches that can be seen from basic economic principles.

The fundamental economic justification for government action to increase innovation in markets is that the private sector will tend to underinvest in R&D because it is not able to fully appropriate the benefits of such investments. The reason for this inappropriability is that the information that results from R&D can be copied by competitors and

the originating firm may, therefore, not be able to recover its costs of creation. In markets that are competitive and in which the industry is at a stage where technology is changing rapidly, investing in R&D is a necessary element for the survival of a producing firm. Innovations in such markets are protected by the fact that it takes a substantial time and effort for competitors to make copies. It is unlikely that firms underinvest in R&D in these markets, and further stimulus to innovation through governmental action is not needed.

In regulated markets and other markets in which barriers to entry are created by governmental action, there is often a variety of administrative obstacles to the introduction of innovation. Deregulation is the most effective mechanism for the stimulation of innovation in these industries.

The objectives of technological innovation for a nation are twofold:

- (1) to maintain or acquire a competitive position in the world market;
- (2) to provide better products and services to the citizens of the nation.

Much of national science and technology policy can be justified by its effectiveness in contributing to the first objective. For example, the use of tax funds in support of education, basic research, and libraries contributes to the development of a national information infrastructure. This infrastructure creates the basis for comparative advantage in international trade in the information-based economies of the modern world. The mechanisms for government action in support of education, basic research, and libraries involve subsidies of these activities. The quality of these activities could probably be improved by giving more control over the character of the services offered to the users rather than the providers of these services. The organizational approach to

providing government support for industrial R&D could also probably be improved. Industry-wide R&D organizations within the government, in government corporations, and in private firms could provide similar services but with different degrees of industry control and confidentiality for innovative ideas.

In many large-scale systems, the evolution of technology has taken place in ways that have been characterized as "autonomous" and "inappropriate," because the technologies seem to have evolved in directions of their own, without regard for human needs. Much of the difficulty can be traced to the fact that these systems are monopolistic; users in these systems do not have an adequate choice. Market-incentive approaches such as deregulation and privatization, offer the most reliable path to the restoration of appropriate innovation. However, in certain areas, such as defense and space, a new approach to science and technology policy that seeks to achieve a more comprehensive approach to system planning may bring innovation that is more appropriate to human needs.

A general conclusion is that there seem to be a number of opportunities for increasing the rate of innovation and for bringing the directions of innovation more closely into line with the needs of users. Most of these opportunities can best be realized by improving the operation of markets by such techniques as deregulation, improving the quality of consumer information, and privatization. A second conclusion is that these improvements could benefit the consumer, both as a member of a nation with a stronger position in the world market and as a consumer of more "appropriate" technology. To obtain these benefits, various forms

of organizational innovation appear to be needed. Studies of new organizational options for the implementation of national science and technology policy would be an essential first step in this innovation process.

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AN INQUIRY INTO THE
HOUSEHOLD ECONOMY

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PROGRAM IN INFORMATION POLICY

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ABSTRACT

Most empirical studies in economics focus on the trading of goods and services, and hence neglect to consider the value of goods and services produced by individuals for themselves and their families. This paper presents an empirical examination of this "household economy".

The principle result of the study is a comparison of the value of the time which people devote to each activity of their lives with the money they spend on the activity. After-tax wage rates are used to value an individual's time.

The enormous size of the household economy, and the fact that for most activities the value of the consumer's time devoted to an activity exceeds the money expenditures on the activity, suggest that there are many opportunities for productivity improvements in the household economy which have been overlooked in most traditional thinking on productivity.

1. INTRODUCTION

Production by consumers has been largely overlooked by economists, yet there is little doubt of its importance. All products and services are purchased by consumers in an unfinished state. The consumer must then do further processing to produce the good or service desired. Lancaster¹ and Becker² have constructed theoretical outlines of this process, yet empirical work has been lacking.

Each household may be viewed as a little corporation, purchasing a variety of inputs and producing a variety of goods and services for its members. These little corporations may be thought of in the aggregate as 'the household economy.' Many outputs of the household economy, for example food preparation or clothes cleaning, differ little from the outputs of some conventional corporations. Yet the economy, as it has been traditionally defined, usually includes only those goods or services produced in return for money payment. It will be referred to here as "the market economy" to emphasize this dichotomy.

¹Kelvin J. Lancaster, 'A New Approach to Consumer Theory', Journal of Political Economy, Vol.74 (April, 1966), pp. 132-157.

²Gary S. Becker, 'A Theory of the Allocation of Time', The Economic Journal, September, 1965, p. 493.

The arbitrariness of the distinction between the two economies is painfully evident. If I pay you to clean my house, and you pay me to clean your house, then both transactions are in the market economy. If we each clean our own houses, or even clean each other's house as a favor, then the activities must be regarded as part of the household economy, as they certainly are not part of the market economy. The constant shifting of activities across the boundary between the two economies may result in misleading inferences. For example, if increasing numbers of women take jobs in the market economy and spend part of their income purchasing services, such as day care, which they used to produce for themselves in the household economy, then the usual measures of the economy, such as Gross National Product (GNP), will indicate a larger increase in production than has actually been the case.

However, this problem of activities shifting across the boundary between the two economies is only one symptom of the fact that a major portion of the economy is simply left out of most conventional economic analysis. This neglect of the household economy is reflected in government policies. In particular, the household economy is neglected in most present thinking on productivity. While much discussion, and some action, is devoted to improving productivity in the market economy, little attention is given to improving prod-

activity in the household economy. Yet it may be argued that improving the productivity of any activity in the household economy would have the same effects on welfare as improving the productivity of an industry of similar size in the market economy.

There are two reasons why the household economy has tended to be neglected by economists. The first has been a definitional problem. Although it is arbitrary, defining the economy to include only those goods or services produced in return for a money payment does create a sharp distinction between activities which are and are not part of the economy. Most alternative definitions require many judgemental distinctions before they can be applied in practice. The only solution would seem to be to regard every activity in which people engage as part of the economy. One may view every activity in which people engage as a service, even if only to the person who produces it.

The second problem is one of data. Data on money transactions are widely collected and distributed. Data on other types of activities are not so readily available. This study is an attempt to pull together available data on the various activities in the household economy, and express this data in money terms. It will be shown that many of the activities in the household economy are 'industries' of

enormous proportions. For most activities, the value of the time which people devote to the activity exceeds the money the people spend on the activity.. Hence, the opportunities for productivity improvement in the household economy are great. Using this data, one may identify specific opportunities which merit further study.

2. THE THEORY

Unfortunately, since household outputs are not sold, it is difficult to place a monetary value on them, so as to compare their value with those of outputs in the market economy. There is, however, one household output which is sold in the market economy--labor. According to economic theory, rational producers will allocate their scarce resources in such a way that the value of the marginal product of the resource is equal in each use. Applying this logic to the allocation of time in the household, it may be argued that time contributed by members of the household should be valued at the wage rate of each individual. Since personal time is really the only scarce resource contributed by the household, it seems reasonable to assume that the value added by the household in producing each good or service is equal to the value of time spent producing the good or service. The total value of each good or service produced by the household is equal to the value of time plus the value

of any inputs purchased in the market economy ('market expenditures') which were used in the activity.

There are at least two objections which may be made to this procedure. The first is that the time which is sold as labor may also produce a service (or disservice) to the individual involved, since people may derive pleasure (or displeasure) from their own labor. The wage rate will not reflect the value of this additional service (or disservice), and hence not be an accurate representation of the true value of peoples' time. Second, people may not be free to adjust their work hours so as to equate the value of the marginal product of time off the job to the wage rate. Unfortunately, there is, as yet, no way to correct for these problems in an empirical study.

Another troublesome problem with valueing peoples' time at the wage rate is that it works only for people who have wages. Perhaps the most notable class of people who would be left out under this scheme are housekeepers. Housekeepers are the professionals of the household economy, and should not be overlooked. As will be discussed below, data are available on time allocations by housewives, who comprise the overwhelming majority of housekeepers. It will be assumed that housewives have an opportunity cost of time (i.e. the wage rate they could make if they were employed in

the market economy) equal to the after-tax wage rate of the average female year-round full-time employee. People who will have to be left out of this analysis due to lack of both time allocation data and the difficulty in estimating wage rates include children, retired people, and the unemployed.

Two major types of data were required by this project. The first type were data on individual time allocations. This data was taken from a 1965 study done by the Survey Research Center at the University of Michigan. For that study, about 2000 non-farm urban-dwellers between the ages of 18 and 65 kept diaries of how they spent a single day. Times reported were coded into one of 96 activity categories. Complete tables were then compiled of time allocations, in average number of minutes per day, for employed men, employed women, and housewives. Tables with less detailed 37 activity categories were also published for specific socio-economic groups, including six household income levels.

The second type of data were on market expenditures. These were taken from the U.S. Bureau of Labor Statistics' Consumer Expenditure Survey, which gives data on consumer expenditures broken down into several hundred categories. The survey was conducted in 1961-62 and again in 1972-73.

This study will use data from the 1972-73 survey, which although a bit more separated in time from the 1965 time allocation data, is more complete and up to date than the 1961-62 survey.

Reconciling the data on time allocations with the data on consumer expenditures poses several problems. First, it is necessary to reconcile the classifications of time allocations with the classifications of market expenditures. Every effort was made to develop as detailed a classification of household activities as the data would allow. A 38 activity classification was ultimately developed. The first 17 activities are what will be called "tradable" activities, since they are direct competitors with services which may be purchased in the market economy. The last 20 activities are called "non-tradable", since the services which result may be consumed only by the person who produces them. Appendix A describes the activity classification and the assumptions behind it in more detail.

The second data reconciliation problem was to find a way to compare data on individual allocations of time with household market expenditures. The solution is to work at the aggregate level. Thus, the sum total value of time devoted to a particular activity by all individuals may be compared to the sum total market expenditures by all households.

Breaking out the data by household income levels is difficult, as the necessary data on individual wage rates by household income class have not been published. These wage rates may be estimated, however. Appendix B explains the methodology which was used to accomplish this.

Calculation of aggregate market expenditures for each activity by income class began by multiplying per household expenditures on each activity for the income class by the number of households in the income class. This did not end the process, however, since there were also some households who did not report their income. Aggregate market expenditures by these families could, however, be calculated by multiplying their expenditures on each activity by the number of households not reporting their income. This amount was then distributed among income classes in proportion to expenditures by families reporting their income in each income class.

3. THE RESULTS

The empirical results of this study are shown in Appendix C. The first three columns for each income class show the average number of minutes per day devoted to each activity, while the fourth column shows the average market expenditures per household per year. Columns five through seven

give the aggregate value of time devoted to the activity by all employed men, employed women, and housewives in the income class, respectively. These figures were obtained by multiplying columns one through three by the corresponding population and wage rate. Column eight is simply the sum of columns five through seven. Column nine gives aggregate market expenditures by all households in the income class on the activity. Column 10 gives aggregate annual person-hours devoted to each activity, obtained by multiplying the figures in columns one through three by the corresponding population size, summing, and making necessary unit changes.

Continuing to the second page for each income class, column one gives the sum of columns eight and nine on the previous page--the total expenditures of time and money on each activity. Column two ranks the activities by total expenditures. Column three gives the market expenditures per person-hour spent on each activity. Hence, it represents the entries in column nine divided by the corresponding entries in column 10 on the previous page. Column four ranks the market expenditures per person-hour. Column five gives the ratio of value of time to total market expenditures. Hence, it represents the entries in column eight divided by the corresponding entries in column nine on the previous page. Column six ranks these ratios.

The third page for each income class shows the assumed population sizes and wage rates for the income class. The total number of employed males and females are based on 1973 averages as reported by the Bureau of Labor Statistics.³ These populations were distributed among income classes in proportion to the aggregate number of person-hours worked, as estimated and Appendix B and shown in Table 9. The total number of housewives is based on the average number of women in 1973 not in the labor force due to the fact that they were "keeping house," as reported by the U.S. Bureau of Labor Statistics.⁴ This total was distributed among income classes in proportion to the number of households in each income class, as shown in the Consumer Expenditure Survey. The total number of households is from the Consumer Expenditure Survey, with households not reporting their income being distributed among income classes in proportion to the number of households reporting an income in the class. Wage rates are as estimated in Appendix B.

³U.S. Bureau of Labor Statistics, Employment and Earnings, U.S. Government Printing Office, January, 1974, p. 145.

⁴Ibid, p. 141.

4. CONCLUSIONS

The household economy far exceeds the market economy in size. If one were to redefine personal consumption expenditures (PCE) to include the value of time expended in the household, the 1973 Gross National Product (GNP) would have been around \$4700 billion, rather than \$1307 billion.⁵ Many of the "industries" of the household economy are gigantic compared to most conventional industries. The value of time and money which are devoted to watching television, for example, far exceeds the market expenditures on either housing or food.

In virtually every activity, the value of time which people devote to the activity exceeds the value of market expenditures on the activity. This suggests a substantial willingness of people to pay for innovations which would reduce the time spent on activities which are displeasureable or neutral. Although this statement may not sound very original, this willingness to pay for time savings may be

⁵This number was obtained by adding my total expense for all families (value of time and market expenditures) of \$4197 billion to the 1973 total of \$497 billion for gross private domestic investment, net exports, and government purchases. The number is approximate, since my definition of market expenditures does not exactly match the standard definition of PCE.

Source: U.S. Bureau of the Census, Statistical Abstract of the United States - 1978, p. 440.

much greater than is commonly perceived. For example, most of us are accustomed to thinking of eating out as an "expensive" activity. Yet, the data in Appendix C indicate that the value of a restaurant customer's time is an average of 1.9 times more valuable than the cost of the meal purchased. The success of the fast-food restaurant industry in recent years may be attributable more to the time savings these establishments offer than to their low prices. If this hypothesis is correct, there is every reason to expect that many people would prefer higher quality food than most fast-food restaurants offer, and be willing to pay for it, if only they could get it quickly. Hence, there is probably a substantial untapped market for high-quality fast-food restaurants.

In general, one might assume that the higher the ratio of time value to market expenditures, the more willing people would be to make a given percentage increase in their expenditures so as to obtain a given percentage decrease in time spent on an activity. House cleaning, with its 19.3 ratio, and personal care at home with a 25.7 ratio would seem ripe for innovation. So would education (2.3 ratio), reading (28.3), and hobbies and crafts (18.8). Although it would require a substantial technological breakthrough, any innovation which could safely and comfortably enable people to reduce the time they spend sleeping would have an enor-

mous impact. People currently spend time with a value roughly equal to the GNP sleeping.

For a few activities, especially medical care and housing, the very low ratios of time value to market expenditure suggest that innovations which allow people to reduce market expenditures by devoting a bit more of their own time to the activity would have an impact. Do-it-yourself solar water heating systems might be one example of such an innovation. Various types of medical monitoring equipment for use in the home might be another.

Interestingly, the ratio of time value to market expenditures are remarkably stable across income classes. There are distinctly higher ratios for food and clothing in lower income classes, indicating a "do-it-yourself" tendency among lower income households. However, the opposite would appear to be true of housing. Perhaps this is because lower income households generally have more modest housing, requiring less care and maintenance than higher income households. As might be expected, market expenditures per hour devoted to an activity rise with income for all activities. In general, one might infer that all income classes would be receptive to innovations which improve household productivity.

There is a need for regular monitoring of the household economy through some indicators similar to those presently used to monitor the market economy. These indicators would not necessarily require the type of detailed time allocation data used in this study, although they could be improved if this type of data were available on a regular basis. Useful indicators of total household production could be developed from existing data on wage rates, employment, and the size of various socio-economic groups. These indicators would remind everyone of what has been demonstrated in this paper--that what most economic planners think of as 'the economy' is merely the tip of the economic iceberg. Hidden underneath are great opportunities for a better life.

Appendix A

DEVELOPING AN ACTIVITY CLASSIFICATION

Every effort was made to develop as detailed a classification of household activities as the data would allow. A 38-activity classification was ultimately developed. These are listed in Table 1, along with the time allocation study⁶ activity classifications assigned to each one.

The 1972-73 Consumer Expenditure Survey, from which data on market expenditures were obtained, had two components. In the first, a sample of about 20,000 households⁷ were asked to keep diaries of all their expenditures over a two week period. In the second, about 20,000 households were asked once each quarter for a year to report expenditures for "big ticket" items. The results of both survey compo-

⁶John P. Robinson, How Americans Use Time; A Social-Psychological Analysis of Everyday Behavior, Praeger Publishers, New York, 1977;

and

John P. Robinson, How Americans Used Time in 1965, Institute for Social Research, University of Michigan, Ann Arbor, 1977. Available from University Microfilms, Ann Arbor, MI.

⁷A household is a group of persons, usually living together, who pool income and expenses, or a financially independent person.

TABLE 1

Assignment of Time Allocation Study Activities to Household
Economy Study Activities

Household Economy Study Activity	Time Allocation Study Activity
Tradable Activities-	
1. Job	00 Normal Occupational Work Outside Home
	01 Normal Occupational Work at Home
	02 Overtime
	03 Travel During Work
	04 Waiting Time or Inter- ruption During Work
	05 Second Job
	07 At Work, Other
	08 Work Breaks
2. Travel to Job	09 Travel to Job
3. Food Preparation	10 Food Preparation
	11 Meal Cleanup
	30 Shopping for Everyday Goods (57%)
	36 Waiting for Purchase of Goods and Services
	39 Travel Associated with Shopping (25%)
	49 Travel Associated with Personal Needs (25%)
4. Cleaning	12 Cleaning House
	13 Outdoor Chores
	30 Shopping for Everyday Goods (3%)
	39 Travel Associated With Shopping (2%)
	49 Travel Associated With Personal Needs (2%)
5. Gardening and Lawn Care	17 Gardening, Animal

	Care (60%)
	30 Shopping for Everyday Goods (1%)
	39 Travel Associated With Shopping (1%)
	49 Travel Associated With Personal Needs (1%)
6. Pet Care	17 Gardening, Animal Care (40%)
	30 Shopping for Everyday Goods (1%)
	39 Travel Associated with Shopping (1%)
	49 Travel Associated with Personal Needs (1%)
7. Clothing and Linens	14 Laundry, Ironing
	15 Clothes Upkeep
	30 Shopping for Everyday Goods (13%)
	35 Repair and Cleaning Services (60%)
	39 Travel Associated with Shopping (14%)
	49 Travel Associated with Personal Needs (14%)
8. House	16 Other Home Repairs
	18 Upkeep of Heat and Water Supplies
	31 Shopping for Durable Goods (90%)
	39 Travel Associated with Shopping (20%)
	49 Travel Associated with Personal Needs (20%)
9. Medical Care Given at Home	41 Personal Medical Care at Home (50%)
	30 Shopping for Everyday Goods (1%)
	39 Travel Associated with Shopping (1%)
	49 Travel Associated with Personal Needs (1%)
10. Child Care	20 Baby Care
	21 Child Care
	22 Helping Child with Homework
	27 Care of Other People's Children
11. Financial Management	19 Household Paperwork

	34 Government Services
	37 Other Professional Services
	39 Travel Associated with Shopping (20%)
	49 Travel Associated with Personal Needs (20%)
12. Travel Associated with Professional Medical Care	39 Travel Associated with Shopping (2%)
	49 Travel Associated with Personal Needs (2%)
13. Travel Associated with Education	59 Travel Associated with Education
14. Travel Associated with Organizations and Religion	69 Travel Associated with Organizations and Religion
15. Travel Associated with Social Life and Entertainment	79 Travel Associated with Social Life and Entertainment
16. Travel Associated with Leisure Activities	89 Travel Associated with Leisure Activities
17. Shopping Associated with Non-Tradable Activities	10 Shopping for Everyday Goods (25%)
	31 Shopping for Durable Goods (10%)
	35 Repair and Cleaning Services (40%)
	39 Travel Associated with Shopping (14%)
	49 Travel Associated with Personal Needs (14%)
Non-Tradable Activities-	
18. Personal Care at Home	40 Personal Hygiene
	48 Other Private Activity
19. Personal Care Services	32 Personal Care Outside Home
20. Medical Care Received at Home	41 Personal Medical Care at Home (50%)
21. Professional Medical Care	33 Medical Care Outside Home
22. Eating at Home	43 Eating at Home

23. Eating Out

- 44 Meals Outside Home
or Workplace**
- 06 Meals at Work**

24. Sleep and Rest

- 44 Essential Sleep**
- 46 Incidental Sleep**
- 47 Resting, Routine Naps**
- 98 Relaxing**

25. Vacation

See Text

26. Education

- 50 Attending Classes as Full-
Time Student**
- 51 Attending Classes as Part-
Time Student**
- 52 Attending Lectures or
Special Talks**
- 53 Political Programs or
Union Training Class**
- 54 Homework or Research**
- 55 Reading Technical
Journals or Books**
- 56 Other Education**

27. Religion

- 64. Participating in
Religious Organizations**
- 65 Religious Services**

28. Other Organizations

- 60 Participating as Member of
Social or Political
Organization or
Labor Union**
- 61 Voluntary Activities as
Elected Official of a
Social or Political
Organization or Labor
Union**
- 62 Participating in Meetings
of Organizations**
- 63 Unpaid Work for a Civic
Purpose**
- 64 Participating in Factory
Council**
- 67 Participating in Other
Organizations**
- 68 Other Organizational
Activity**

29. Television

91 Television

30. Reading

- 93 Reading Books**
- 94 Reading Magazines**
- 95 Reading Newspapers**
- 99 Reading, Not Specified**

31. Social Life

- 24 Indoor Play with Children
- 42 Care and Help Given to
Other Adults
- 75 Entertaining or Visiting
Friends
- 76 Parties or Receptions
- 77 Going to Bars, Tearooms,
Soda Fountains, etc.
- 78 Other Social Life
- 87 Parlor Games

32. Conversation

- 23 Read or Talk with
Children
- 96 Talking with Adults

33. Outdoors

- 25 Walking or Playing
Outdoors with Children
- 80 Playing Sports or Physical
Exercises
- 81 Hunting, Fishing, Camping,
Pleasure Drives,
Sightseeing
- 82 Talking a Walk or Hike

34. Entertainment

- 70 Attending Sports Events
- 71 Circuses, Fairs,
Nightclubs, Dancing
Parades
- 72 Attending Movies
- 73 Attending Theater,
Concerts or Opera
- 74 Attending Museums,
Exhibitions, or
Galleries

35. Listening to Sounds

- 19 Listening to Records
or Tape Recording
- 22. Listening to Radio

36. Performing

- 86 Playing a Musical
Instrument, Singing,
Artistic Dancing

37. Hobbies and Crafts

- 83 Hobbies and Collections
- 84 Women's Home Crafts
- 85 Artistic Hobbies
- 88 Other Leisure

38. Personal Letters

- 97 Writing Private
Correspondence

nents have been compiled as an integrated set of tables.⁸ However, a greater level of commodity detail is provided in the separate publications on each segment of the survey.⁹ Both surveys were done over a two-year period, with no adjustments made for price changes over that time. Hence, the expenditures shown may be viewed as averages of expenditures over this period. The diary survey began six-months later than the interview survey, with price level adjustments being made to ensure that the integrated diary and interview survey data reflected calendar years 1972-73. Data are presented according to various socio-economic breakdowns, including 12 household income levels and seven occupational groups.

Table 2 shows the consumer expenditure classes assigned to each household activity. Whenever possible, the classes come from among those used in the integrated diary and interview survey data. In some cases, these classes did not provide sufficient detail for this study. The separate diary and interview survey publications provided a more de-

⁸U.S. Bureau of Labor Statistics, Consumer Expenditure Survey: Integrated Diary and Interview Survey Data, 1972-73, Bulletin 1992, U.S. Government Printing Office, Washington, DC, 1978.

⁹U.S. Bureau of Labor Statistics, Consumer Expenditure Survey: Diary Survey, July 1972-June 1974, Bulletin 1959, U.S. Government Printing Office, Washington, DC, 1977;

and

U.S. Bureau of Labor Statistics, Consumer Expenditure Survey: Interview Survey, 1972-73, Bulletin 1997, U.S. Government Printing Office, Washington, DC, 1978.

tailed breakdown of many of these classes, which were used where necessary. Where data was taken from one of the separate survey publications, this is indicated by a footnote in Table 2.

With three exceptions, expenditures reported from the broad classes shown in the integrated diary and interview survey publication equaled the sum of the corresponding more detailed expenditure classes in the interview survey publication, where the data from the interview survey was used in this study. Thus, this detailed expenditure data from the interview survey publication was directly comparable to the expenditure data reported in the integrated publication, and could be used without modification. In three exceptional cases small adjustments were made, as explained in the footnotes to Table 2, to insure comparability of this data.

Expenditure data for the classes in the integrated publication never exactly equal the sum of the expenditures shown for the corresponding more detailed classes in the diary survey publication, due to price level adjustments made to this data in the integration process by the Bureau of Labor Statistics. These adjustments were made due to the fact that the diary survey actually began six months after the interview survey, as explained above. Where diary survey data were used, expenditures shown in the diary survey were

TABLE 2

Assignment of Consumer Expenditure Classes to Household
Economy Study Activities

Household Economy Study Activity	Consumer Expenditure Survey Class
Tradable Activities-	
1. Job	
2. Travel to Job	Transportation (35.4%)
3. Food Preparation	Food at Home (98%) Refrigerators and Freezers (1) Cooking Ranges (1) Dishwashers and Garbage Disposals (1) Toasters, Coffeemakers, Blenders (1) Range Hoods and Electric Kitchen Equipment (1) Domestic Services- Domestic and Other Duties (50%) (2) Housewares Miscellaneous House- hold Products (50%)(3) Service Contracts on Appliances (50%)(4) Transportation (8.7%)
4. Cleaning	Cleaning Supplies (3) Vaccuums and Other Electric Floor Equipment (1) Domestic Services- Domestic and Other Duties (50%)(2) Transportation (.5%)
5. Gardening and Lawn Care	Gardening and Lawn Care Services (2) Fertilizers and Pesticides (2) Lawn and Garden Supplies (3) Lawnmowers (4) Transportation (.3%)
6. Pets and Animals	Pet Purchases, Supplies, and Other (1) Pets, Toys, and Games (10%) Food at Home (2%)

7. Clothing and Linens

Transportation (.3%)

Laundry Supplies (3)
Clothing Purchases
Dry Cleaning and Laundry
Washing Machines (1)
Clothes Dryers (1)
Sewing Machines (1)
Household Textiles
Paper Towels, Napkins
and Tissues (66%)(3)
Service Contracts on
Appliances (50%)(4)
Transportation (6%)

8. House

Shelter
Other Household Repairs (2)
Reupholstering and
Furniture Repair (2)
Appliance Repair and
Servicing (2)
Moving, Freight, and
Storage Charges (2)
Fuel and Utilities
Furniture
Floor Coverings
Heaters, Fans, Humid-
ifiers, Vaporizers (1)
Miscellaneous Items (2)
Dehumidifiers, Air
Conditioners (1)
Miscellaneous Household
Products (50%)(3)
Lamps, Chandeliers, and
Other Fixtures (4)
Window Shades, Blinds,
and Rods (4)
Clocks, Mirrors and
Decorative Items (4)
Hand and Power Tools (4)
Insurance on Personal
Effects (4)
Other Household Expenses (1)
Transportation (2.5%)

**9. Medical Care Given
at Home**

Nonprescription Drugs and
Medical Supplies
Domestic Services-
Child Care and Care
for Elderly (50%)(2)
Transportation (5.4%)

10. Child Care

Toys (1)
Pets, Toys and Games (45%)

	Domestic Services- Child Care and Care for the Elderly (50%)(2) Transportation (5.4%)
11. Financial Management	Stationary and Greeting Cards (50%)(3) Personal Insurance, Retirement and Pensions Miscellaneous Typewriters and Home Use Office Equipment Transportation (5.2%)
12 Travel Associated with Professional Medical Care	Transportation (2%)
13. Travel Associated with Education	Transportation(1%)
14. Travel Associated with Organizations and Religion	Transportation (5.3%)
15. Travel Associated with Social Life and Entertainment	Transportation (15.6%)
16. Travel Associated with Leisure Activities	Transportation (2.7%)
17. Shopping Associated with Non-Tradable Activities	Transportation (8.6%)
Non-Tradable Activities-	
18. Personal Care at Home	Personal Care Products (5) Paper Towels, Napkins, and Tissues (3)
19. Personal Care Outside Home	Personal Care Services (5)
20 Medical Care Received at Home	
21. Professional Medical Care	Health Care Expenses Not Covered by Insurance Health Insurance
22. Eating at Home	

23. Eating Out	Food Away from Home Meals as Pay
24. Sleep and Rest	
25. Vacation	Vacation and Pleasure Trips Owned Vacation Home Luggage, Footlockers, and Trunks (4)
26. Education	Education
27. Religion	Gifts to Religious Organizations (6)
28. Other Organizations	Gifts to Welfare Organizations (6) Gifts to Educational, Political, and Other Organizations (6)
29. Television	Television Television Cable Services (1) TV, Radio, Musical Instrument, and Other Repairs and Rentals (60%)(1)
30. Reading	Reading
31. Social Life	Pets, Toys, and Games (45%) Gifts to Individuals Outside Family (6) Alcoholic Beverages Tobacco Products and Smoking Supplies
32. Conversation	Telephone
33. Outdoors	Boats, Aircraft and Wheel Goods Club and Membership Dues (1) Bicycles, Tricycles, and Powered Carts (1) Sports Equipment (1) Playground, Camping, and Other Equipment (1)
34. Entertainment	Season Tickets, Admissions, and Fees (1)
35. Listening to Sounds	Radios (1) Phonographs, Tape Recorders, and Other (1) Component Systems, Parts and Other (1)

	Records, Reels, and Cassetts (1) TV, Radio, Musical Instrument, and Other Repairs and Rentals (40%) (1)
36. Performing	Musical Instruments and Accessories (1) Lessons (40%)(1)
37. Hobbies and Crafts	Photography (1) Lessons (40%)(1)
38. Personal Letters	Stationary and Greeting Cards (50%)(3)

(1) Taken from interview survey publication.

(2) The integrated diary and interview survey publication gives one figure for "Domestic and Other Household Services", which includes the following classifications from the interview survey publication:

- Domestic Services-Domestic and Other Duties
- Domestic Services-Child Care and Care for Elderly
- Gardening and Lawn Care Services
- Other Household Repairs
- Reupholstering and Furniture Repair
- Appliance Repair and Servicing
- Moving, Freight, and Storage Charges
- Fertilizers and Pesticides

However, these classifications do not sum to match the total shown in the integrated publication. The difference is evidently due to the inclusion of a few miscellaneous items from the diary survey, including locksmith services, small houseplants, seeds, and bulbs. This was resolved by using the figures for the above classifications shown in the interview survey publication, and creating a new classification "Miscellaneous Items" for the difference between the total expenditures for the above classifications and the total expenditures shown in the integrated publication.

(3) These classifications were lumped together under the heading of "Housekeeping and Laundry Supplies" in the integrated diary and interview survey publication. Detailed expenditure data was taken from the diary survey publication, and scaled to make the total of all these classifications match the total shown in the integrated publication.

(4) The integrated diary and interview survey publication gives one figure for "Miscellaneous Household Expense", which includes these classifications from the interview survey publication. However, expenditures on these classifications do not match the total shown in the integrated publication. The difference is evidently due to the inclusion of expenditures on sheds from the diary

survey. This was resolved by adding the difference between the total of these classifications shown in the interview survey publication and the total shown in the integrated publication to the figure for "Other Household Expenses." Expenditures on other classifications were taken directly from the interview survey publication.

(5) These classifications were lumped together under the heading of "Personal Care" in the integrated diary and interview survey publication. Detailed expenditure data was taken from the diary survey publication, and scaled to make the total of all these classifications match the total shown in the integrated publication.

(6) The integrated diary and interview survey publication gives one figure for "Gifts and Contributions", which includes these classifications from the interview survey publication. However, expenditures on these classifications do not sum to match the total shown in the integrated publication. The difference is evidently due to the inclusion of some small contributions from the diary survey. This was resolved by scaling the detailed expenditure data to make the total of all these classifications match the total shown in the integrated publication.

scaled by the factor necessary to ensure that the expenditure shown for a class in the integrated publication equaled the sum of the corresponding expenditures in the diary survey publication.

The most troublesome group of activities to deal with in developing this classification were those related to travel. They will be regarded as tradable, since even though it is not possible to pay someone else to do one's own traveling, it is generally possible to pay to have whatever one is traveling to brought to one's home. For example, if one does not wish to travel to school, one could hire a tutor to give lessons at home. In this sense, travel competes directly with services offered in the market economy.

With the exception of "Travel to Job", the time and expense of travel associated with tradable activities (numbers 3-11) were included in the times and expenses of these activities. "Travel to Job" was felt to be so important that it was made a separate activity. Since travel was considered to be a tradable activity, it seemed inappropriate to include the time and expense of travel associated with non-tradable activities in the times and expenses allocated to these activities. Hence, five special tradable activities were created for them (numbers 12-16).

Travel while on vacation was considered to be different from other types of travel associated with non-tradable activities, since one cannot generally pay to have the vacationland brought to one's home. Furthermore, vacation travel may be an integral part of the activity of vacationing, not simply something which must be done in order to carry out some other activity, as is usually the case for travel associated with other activities. Hence, the time and expense of vacation travel was included in the activity "vacation".

Shopping is similarly a tradable activity, which is associated with most activities, both tradable and non-tradable. The time spent on shopping associated with activities 2-16 were included in the time of these activities, while the time spent on shopping associated with non-tradable activities 18-38 were made into a separate activity "Shopping Associated With Non-Tradable Activities."

Unfortunately, the time allocation study does not break down time spent traveling and shopping into this much detail. While travel activities 13-16 are broken out, as well as travel to job and travel associated with child care, all other travel in the time allocation study is lumped together under "Travel Associated with Purchasing Goods and Services" and "Travel Associated with Personal Needs".

Shopping is broken down into only "Shopping for Everyday Goods", "Shopping for Durable Goods", and "Waiting for Purchase of Goods and Services." There is very little published data which could be used to further breakdown these classifications. Even if data on time allocations by detailed purpose of trip had been collected, it would be difficult to analyze, since consumers so frequently do several types of shopping and errands on a single trip. A Federal Highway Administration study provides some very limited guidance.¹⁰ The sum total of the time allocations for "Travel Associated with Purchasing Goods and Services" and "Travel Associated with Personal Needs" were allocated among activities based on estimates made by the author. Similarly, the time allocations for shopping were allocated among activities based on estimates made by the author. The percentage of the total allocated to each activity is indicated in Table 1.

Except for transportation expenditures while on vacation, the consumer expenditure survey provides no breakdown of transportation expenses by purpose of trip. Transportation expenses were therefore distributed among activities in pro-

¹⁰U.S. Federal Highway Administration, Nationwide Personal Transportation Study; Report no. 10: Purposes of Automobile Trips and Travel, Washington, DC, May, 1974. Additional data from this study is presented in U.S. Department of Transportation, 1974 National Transportation Report, Washington, DC, July, 1975, pp. 133-134.

portion to a weighted average of the travel times of employed men, employed women, and housewives allocated to each activity. The percentage of total non-vacation transportation expense allocated to each activity is indicated in Table 2.

The time allocation study did not survey people who were on overnight trips, hence most vacation time was excluded. In order to estimate time spent vacationing, it is necessary to turn to the Census of Transportation. The average trip duration is estimated from the following distribution of trip durations:¹¹

Duration	1967 Total Person-Trips (millions)	Percent Non-Business
1 Day	31.5	73.6
1 Night	89.7	84.2
2 Nights	94.1	88.6
3 to 5 Nights	75.7	84.9
6 to 9 Nights	34.8	92.5
10 to 15 Nights	20.3	92.2
>16 Nights	15.1	89.3

One day trips will be ignored, as presumably they were included in the time allocation survey under one of the leisure activities. It will be assumed that one night trips lasted an average of 24 hours; two night trips lasted an average of 48 hours; three to five night trips lasted an aver-

¹¹U.S. Bureau of the Census, 1967 Census of Transportation; Volume I, National Travel Survey, Washington, DC, July, 1970, p. 24.

age of 96 hours; six to nine night trips lasted an average of 180 hours; ten to fifteen night trips lasted an average of 300 hours; and sixteen nights or more trips lasted an average of 480 hours. Using the number of non-business trips as a weighting factor, an average trip duration of 104 hours may be obtained.

The Census of Transportation also provides data on the number of trips by household income level. From this, the average annual number of non-business overnight trips per person by income level may be calculated (see Table 3). Multiplying this average number of trips by average trip duration of 104 hours gives the following annual number of hours per person spent on overnight vacation trips by income class:

Household Income Level (1967)	Average Annual Number of Hours Spent on Overnight Vacation Trips Per Person
<\$4000	98
\$4,000-\$5,999	185
\$6,000-7,499	205
\$7,500-9,999	168
\$10,000-14,999	140
\$15,000	131
All	151

Estimated average number of minutes per day spent on the activity "vacation" were obtained by simply converting these figures into units of minutes per day. The time spend on all other activities were scaled down to ensure than the sum of all daily activities equaled 1440 minutes (24 hours).

TABLE 3

Calculation of the Annual Number of Non-Business Trips Per Person

Household Income Level	1967 Number of Trips(1)	Percent Non- Business	Estimated Popula- tion(2)	Average Annual Non- Business Trips Per Person
<\$4,000	38.5	91.5	37.4	.94
\$4,000-5,999	52.4	92.5	27.3	1.78
\$6,000-\$7,499	53.5	90.4	24.5	1.97
\$7,500-9,999	70.6	88.0	38.3	1.62
\$10,000-14,999	73.4	80.7	43.9	1.35
>\$15,000	41.3	74.0	24.3	1.26
Total	329.7	86.0	195.8	1.45

1) The number of trips for each family income level was scaled to give a total of 329.7 million trips, the number of trips of one night or more duration recorded above.

2) Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 59, "Money Income in 1967 of Families," U.S. Government Printing Office, Washington, DC, April, 1969, pp. 39,41. Represents sum of families and unrelated individuals. The Census Bureau's \$7,000-7,999 income class was divided evenly between the \$6,000-\$7,499 and \$7,500-9,999 income classes.

Appendix B

ESTIMATION OF AVERAGE WAGE RATES BY HOUSEHOLD INCOME CLASS

Average wage rates by household income class may be obtained by estimating aggregate earnings¹² after taxes by all persons in an income class, and dividing this by an estimate of the aggregate number of person-hours worked by individuals in the income class. Aggregate earnings for an income class may be estimated by multiplying average earnings of each household in an income class by the total number of households in the income class. Both sets of data are given by the Consumer Expenditure Survey. Aggregate earnings may then be multiplied by one minus the tax rate to give aggregate earnings by families after taxes (see Table 4). The Consumer Expenditure Survey shows taxes paid by each type of tax, hence the tax rate may be easily calculated. The tax rate includes federal, state, and local income taxes. Although it would be appropriate to include Social Security taxes in the tax rate as well, the Consumer Expenditure Survey includes Social Security taxes in the "Health Insurance"

¹²As used in this report, "earnings" refers only to wages, salaries, and self-employment income, while "income" includes transfer payments, such as social security and welfare, and property income, such as rents and dividends.

and "Personal Insurance, Retirement, and Pensions" categories. It is unfortunately not possible to recover the cost of Social Security taxes from this data. After-tax wages will be used in this study, since the after-tax wage is the value of time as perceived by the individual involved.

TABLE 4

Aggregate Annual Earnings by Income Class

Household Income Class	Number of House- holds(1) (Millions)	Earnings Per Household (\$)	Aggregate Earnings (Mil- ion\$)	Tax Rate	Aggregate Earnings After Tax (Mil- lion \$)
<\$3,000	9.572	292.48	2799.6	3.8%	2693.2
\$3,000-3,999	4.214	1198.56	5050.7	3.6%	4868.9
\$4,000-4,999	3.827	2115.49	8095.0	4.9%	7699.3
\$5,000-5,999	3.466	3006.97	10422.2	6.7%	9723.9
\$6,000-6,999	3.591	4120.37	14796.2	7.9%	13,627.3
\$7,000-7,999	3.43	5350.16	18351.0	9.7%	16,571.0
\$8,000-9,999	6.963	7018.49	48,870.0	11.2%	43,396.3
\$10,000-11,999	6.629	9422.01	62,458.5	12.9%	54,501.4
\$12,000-14,999	8.844	11,784.39	104,221.1	14.0%	89,630.2
\$15,000-19,999	10.555	15,504.39	163,648.1	15.2%	138,774.2
\$20,000-24,999	5.309	20,211.54	107,303.1	16.6%	89,490.8
>\$25,000	4.815	32,654.29	157,230.4	18.6%	127,985.6

(1) 3.773 million households who did not report their income were distributed over income classes in proportion to the number of households reporting an income in each class.

Source: U.S. Bureau of Labor Statistics, Consumer Expenditure Survey: Integrated Diary and Interview Survey Data, Bulletin 1992, U.S. Government Printing Office, Washington, DC, 1978, pp. 24-35.

Calculation of the aggregate number of person-hours worked by income class is a bit more difficult. Beginning with the year 1975, the Census Bureau began publishing data on the number of full-time year-round earners¹³ per family by income class. Thus, one can estimate the number of full-time year-round earners in families simply by multiplying the number of families by the number of full-time year-round earners (see Table 5).

The Census Bureau, however, defines a family as two or more persons related by blood, marriage, or adoption living together. Since this study is concerned with all households, including those consisting of only one person, it is necessary to add the number of full-time year-round earners among what the Census Bureau calls "unrelated individuals." Fortunately, data has also been published on this (see Table 6). The result is the number of full-time year-round earners in each income class.

The total number of full-time earners may be estimated from these figures by assuming the number of full-time earners in each income class is proportional to the number of full-time year-round earners. Thus, the total number of full-time earners is distributed among income classes in

¹³A "year-round" earner is someone who was employed 50 or more weeks in the previous year.

TABLE 5

Number of Full-Time Year-Round Earners in Families

Household Income Class	Number of Families(1) (000)	Full-Time Year-Round Earners Per Family(2)	Family Full-Time Year-Round Earners (000)
<\$1,000	605.58	.22	133.23
\$1,000-1,499	385.37	.22	84.78
\$1,500-1,999	605.58	.22	133.23
\$2,000-2,499	770.74	.11	84.78
\$2,500-2,999	935.90	.11	102.95
\$3,000-3,499	1101.06	.10	110.11
\$3,500-4,000	1156.11	.10	115.61
\$4,000-4,999	2477.39	.17	421.16
\$5,000-5,999	2532.44	.26	658.43
\$6,000-6,999	2642.54	.34	898.46
\$7,000-7,999	2697.60	.46	1240.90
\$8,000-8,999	2807.70	.53	1488.08
\$9,000-9,999	2697.60	.64	1726.46
\$10,000-11,999	5890.67	.75	4418.00
\$12,000-14,999	8147.84	.92	7496.01
\$15,000-24,999	14,478.94	1.19	17,229.94
\$25,000-\$49,999	4569.40	1.47	6717.02
>\$50,000	550.53	1.16	638.61

(1) Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 97, "Money Income in 1973 of Families and Persons in the United States", U.S. Government Printing Office, Washington, DC, 1975, p. 46.

(2) Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 105, "Money Income in 1975 of Families and Persons in the United States", U.S. Government Printing Office, Washington, DC, 1977, p. 112.

proportion to the number of full-time year-round earners.

In a similar fashion, the number of part-time earners in each income range may be obtained by distributing the total number of part-time earners over the income ranges in proportion to the number of full-time year-round earners in

TABLE 6

**Number of Full-Time Year-Round Earners Among Unrelated
Individuals**

Household Income Class	Number of Unrelated Indiv- iduals(1) (000)	Full-Time Year-Round Earners Per Unrelated Indiv- idual(2)	Unrelated Individual Full-Time Year-Round Earners (000)
<\$1000	1387.76	.082	113.80
\$1,000-1,499	1168.64	.040	46.75
\$1,500-1,999	1442.54	.024	34.62
\$2,000-2,499	1679.92	.029	48.72
\$2,500-2,999	1278.20	.030	38.35
\$3,000-3,499	1095.60	.059	64.64
\$3,500-3,999	858.22	.105	90.11
\$4,000-4,999	1698.18	.192	326.05
\$5,000-5,999	1296.46	.300	388.94
\$6,000-6,999	1040.82	.435	452.76
\$7,000-7,999	931.26	.498	463.77
\$8,000-8,999	858.22	.574	492.62
\$9,000-9,999	675.62	.626	422.94
\$10,000-11,999	1004.30	.706	709.04
\$12,000-14,999	913.00	.749	683.84
\$15,000-24,999	766.92	.792	607.40
\$25,000-49,999	127.82	.812	103.79
>50,000	54.78	.711	38.95

(1) Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 97, U.S. Government Printing Office, Washington, DC, 1975, p. 47.

(2) Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 105, U.S. Government Printing Office, Washington, DC, 1977, p. 155

each range (see Table 7). The total number of person-hours worked may be obtained by assuming each full-time earner works 40 hours a week 52 weeks a year, while each part-time earner works 20 hours a week 52 weeks a year.

TABLE 7

Aggregate Person-Hours Worked

Household Income Class	Total Full-Time Year Round Earners (000)	Total Estimated Full-Time Earners (000)	Total Estimated Part-Time Earners (000)	Total Annual Person Hours Worked(2) (Millions)
<\$1,000	247.0	354.4	72.6	812.6
\$1,000-1,499	131.5	188.7	38.7	433.2
\$1,500-1,999	167.9	240.9	49.4	552.4
\$2,000-2,499	133.5	191.5	39.3	439.2
\$2,500-2,999	141.3	202.7	41.6	464.9
\$3,000-3,499	174.8	250.8	51.4	575.1
\$3,500-3,999	205.7	295.1	60.5	676.7
\$4,000-4,999	747.2	1072.1	219.7	2458.5
\$5,000-5,999	1047.4	1502.8	308.0	3446.1
\$6,000-6,999	1351.2	1938.6	397.3	4445.5
\$7,000-7,999	1704.7	2445.8	501.3	5608.6
\$8,000-8,999	1980.7	2841.8	582.5	6516.7
\$9,000-9,999	2149.4	3083.9	632.1	7071.9
\$10,000-11,999	5127.0	7356.0	1507.7	16,868.5
\$12,000-14,999	8179.9	11,736.2	2405.5	26,913.0
\$15,000-24,999	17,837.3	25,592.2	5245.4	58,687.0
\$25,000-49,999	6820.8	9786.2	2005.8	22,441.3
>50,000	677.6	972.2	199.3	2229.4

(1) Source: Total number of full-time and part-time employed persons from U.S. Bureau of Labor Statistics, Employment and Earnings, U.S. Government Printing Office, Washington, DC, January, 1974, p. 145. Figures based on annual averages for 1973.

(2) See text.

This procedure probably tends to understate the number of employees in the lower income ranges, where people probably work on a more intermittent basis, but it seems to be about the best which can be done with available data. 1973 Census data will be used throughout to ensure comparability with

the Consumer Expenditure Survey, except for the number of full-time year-round earners per family by income class, which will be for 1975, the first year it was published.

Before proceeding to divide aggregate earnings by hours worked, it is necessary to reconcile the income classes used in the various data sources. Since the income classes given for the time allocation study are for the year 1965, they must be adjusted for inflation to make them comparable to the remaining data, which is for the year 1973. One 1965 dollar had the purchasing power of 1.4 1973 dollars, according to the consumer price index. Table 8 shows the household economy study income classes used here, and the corresponding income classes in the data sources. It was necessary to split the Census Bureau's \$15,000-25,000 income class between the \$12,000-19,999 and >\$20,000 classes used here. This was done by dividing the earnings in the \$15,000-\$25,000 income class between the two classes in proportion to the number of households in the two classes, as reported in the Consumer Expenditure Survey.

Table 9 shows the average after-tax wage rates which result from dividing aggregate earnings by aggregate person-hours worked. There are, however, significant differences in earnings between the sexes. The average full-time year-round male earner earned 1.158 times as much as the average

TABLE 8

Correspondence of Income Classes

Household Economy Study Income Class (1973 \$)	Time Allocation Study Income Class (1965 \$)	Census Bureau Income Class (1973 \$)	Consumer Expenditure Study Income Class (1973 \$)
<\$5,000	<\$4,000	<\$1,000	<\$3,000
		\$1,000-1,499	\$3,000-3,999
		\$1,500-1,999	\$4,000-4,999
		\$2,000-2,499	
		\$2,500-2,999	
		\$3,000-3,499	
		\$3,500-3,999	
		\$4,000-4,999	
\$5,000-7,999	\$4,000-5,999	\$5,000-5,999	\$5,000-5,999
		\$6,000-6,999	\$6,000-6,999
		\$7,000-7,999	\$7,000-7,999
\$8,000-9,999	\$6,000-7,499	\$8,000-8,999	\$8,000-9,999
		\$9,000-9,999	
\$10,000-11,999	\$7,500-9,999	\$10,000-11,999	\$10,000-11,999
\$12,000-19,999	\$10,000-14,999	\$12,000-14,999	\$12,000-14,999
		\$15,000-25,000*	\$15,000-19,999
>\$20,000	>15,000	\$15,000-25,000*	\$20,000-24,999
		>25,000	\$25,000-49,999
			>\$50,000

*Number of earners in \$15,000-25,000 income class allocated between \$12,000-19,999 and >\$20,000 household economy study income classes in proportion to the number of families in each class, as reported in the Consumer Expenditure Survey.

full-time year-round earner, while the average full-time year-round female earner earned only .637 times as much as the average full-time year-round earner.¹⁴ It will be assumed that these same ratios apply to all types of earners at all income levels.

TABLE 9

Average Wage Rates

Household Economy Study Income Class	Aggregate Earnings (Million \$)	Aggregate Person-Hours Worked (Millions)	Hourly Wage (After Tax \$)
<\$5,000	15,261.4	6412.6	2.38
\$5,000-7,999	39,922.2	13,500.2	2.96
\$8,000-9,999	43,396.3	13,588.6	3.19
\$10,000-11,999	54,401.4	16,868.5	3.23
\$12,000-19,999	228,404.4	65,959.5	3.46
>\$20,000	217,476.4	44,311.2	4.91
Total	598,862.1	160,640.5	3.73

The before-tax wage rate for housewives was assumed equal to the average earnings of a full-time year-round female earner in 1973 of \$6661 per year¹⁵ or \$3.20 per hour. The after-tax wage rate for housewives was calculated for each income class by multiplying this by one minus the tax rate for the income class. The tax rates are a weighted average of those shown in Table 4, where the weighting is by number of households.

¹⁴U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 97, U.S. Government Printing Office, Washington, DC, 1975, pp. 137-139.

¹⁵U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 97, "Money Income in 1973 of Families and Persons in the United States", U.S. Government Printing Office, 1975, p. 139.

APPENDIX C

VALUE OF TIME VS. MARKET EXPENDITURES
BY INCOME CLASSES

VALUE OF TIME VS. MARKET EXPENDITURES FOR THE UNDER \$5000 HOUSEHOLD INCOME CLASS

ACTIVITY	MINUTES/DAY				1973 \$/HOUSE-				BILLION 1973 \$				PERSON HOURS (MIL- LIONS)
	EMPLOYED MEN	EMPLOYED WOMEN	HOUSE- HIVES	HOLD MARKET- ITURES	EMPLOYED MEN VALUE OF TIME	EMPLOYED WOMEN VALUE OF TIME	HOUSE- HIVES VALUE OF TIME	TOTAL VALUE OF TIME	TOTAL MARKET- ITURES	PERSON HOURS (MIL- LIONS)	TOTAL MARKET- ITURES	PERSON HOURS (MIL- LIONS)	
1 JOB	426.75	303.76	9.95	0.0	14.84	3.63	1.62	20.09	0.00	8292.8	0.00	8292.8	
2 TRAVEL TO JOB	34.16	32.57	1.28	194.1	1.19	0.39	0.21	1.79	3.42	754.5	3.42	754.5	
3 FOOD PREPARATION	29.09	79.46	160.09	756.0	1.01	0.95	25.04	28.00	13.31	9473.8	13.31	9473.8	
4 HOUSE CLEANING	7.01	38.88	72.49	29.1	0.24	0.45	11.79	12.50	0.49	4234.9	0.49	4234.9	
5 GARDENING	1.49	1.24	2.35	24.7	0.05	0.01	0.38	0.45	0.43	152.8	0.43	152.8	
6 PET CARE	1.11	0.93	1.71	28.2	0.04	0.01	0.28	0.33	0.50	111.8	0.50	111.8	
7 CLOTHING AND LINENS	6.41	26.22	51.69	325.7	0.22	0.31	0.41	8.94	5.75	3025.8	5.75	3025.8	
8 HOUSE	12.37	5.21	9.05	1150.9	0.43	0.06	1.47	1.96	20.27	676.3	20.27	676.3	
9 MEDICAL CARE GIVEN	0.56	0.56	0.79	44.9	0.02	0.01	0.13	0.16	0.79	53.5	0.79	53.5	
10 CHILD CARE	3.72	25.75	92.99	42.7	0.13	0.71	16.26	16.70	0.87	5547.4	0.87	5547.4	
11 FINANCIAL MANAGEMENT	21.88	24.28	22.54	163.1	0.76	0.29	3.67	4.72	2.87	1650.6	2.87	1650.6	
12 TRAVEL/PRO MEDICAL	0.51	0.39	0.48	11.0	0.02	0.00	0.08	0.10	0.19	35.1	0.19	35.1	
13 TRAVEL/EDUCATION	0.84	0.41	0.51	5.5	0.03	0.00	0.08	0.12	0.10	40.9	0.10	40.9	
14 TRAVEL/ORG & RELIGION	3.37	2.47	2.55	29.1	0.12	0.03	0.41	0.56	0.51	197.0	0.51	197.0	
15 TRAVEL/SOCAL LIFE	10.12	8.23	6.63	85.5	0.35	0.10	1.08	1.53	1.51	543.4	1.51	543.4	
16 TRAVEL/LEISURE	1.69	1.65	1.02	14.8	0.06	0.02	0.17	0.24	0.26	88.2	0.26	88.2	
17 SHOPPING/NOH-TRADABLE	7.23	6.69	8.33	47.2	0.25	0.09	1.35	1.69	0.83	595.0	0.83	595.0	
TOTAL--TRADABLE	560.33	558.69	451.43	2959.3	19.76	6.69	73.43	99.07	52.11	35474.0	52.11	35474.0	
18 PERSONAL CARE HOME	52.14	75.18	49.20	36.7	1.81	0.90	8.02	10.73	0.65	3859.3	0.65	3859.3	
19 PERSONAL CARE SERVICES	0.91	2.03	1.43	42.7	0.03	0.02	0.23	0.29	0.75	103.2	0.75	103.2	
20 MED CARE RECEIVE PHONE	0.23	0.25	0.36	0.0	0.01	0.00	0.06	0.07	0.00	23.8	0.00	23.8	
21 PRO MEDICAL CARE	0.91	1.02	1.43	247.3	0.03	0.01	0.23	0.28	4.35	95.2	4.35	95.2	
22 EATING AT HOME	58.77	43.71	48.54	0.0	2.04	0.52	7.96	10.53	0.00	3677.3	0.00	3677.3	
23 EATING OUT	32.99	21.85	4.14	160.0	1.15	0.26	0.67	2.08	2.83	506.7	2.83	506.7	
24 SLEEP AND REST	467.04	468.18	536.31	0.0	16.24	5.60	87.24	109.08	0.00	37933.6	0.00	37933.6	
25 VACATION	16.20	16.13	16.21	72.1	0.56	0.19	2.64	3.39	1.27	1189.8	1.27	1189.8	
26 EDUCATION	19.53	12.03	0.00	15.0	0.68	0.14	0.00	0.83	0.26	342.0	0.26	342.0	
27 RELIGION	3.22	12.68	12.79	53.9	0.11	0.15	2.08	2.34	0.95	818.1	0.95	818.1	
28 OTHER ORGANIZATIONS	0.00	9.47	0.43	15.1	0.00	0.11	0.07	0.18	0.27	97.2	0.27	97.2	
29 TELEVISION	81.67	94.59	151.70	30.5	2.84	1.13	24.68	28.65	0.54	9810.9	0.54	9810.9	
30 READING	25.86	22.30	15.97	19.1	0.90	0.27	2.60	3.76	0.34	1347.6	0.34	1347.6	
31 SOCIAL LIFE	48.59	50.35	54.37	221.9	1.69	0.60	15.35	17.64	3.91	6008.7	3.91	6008.7	
32 CONVERSATION	22.86	19.68	33.98	107.2	0.79	0.24	5.53	6.55	1.89	2243.2	1.89	2243.2	
33 OUTDOORS	12.00	0.70	8.52	21.8	0.42	0.01	1.39	1.81	0.38	603.4	0.38	603.4	
34 ENTERTAINMENT	15.53	17.27	0.00	13.1	0.54	0.21	0.00	0.75	0.23	331.4	0.23	331.4	
35 LISTENING TO SOUNDS	11.04	4.78	4.47	26.3	0.39	0.06	0.73	1.17	0.46	413.4	0.46	413.4	
36 PERFORMING	0.22	0.28	0.56	3.2	0.01	0.00	0.09	0.10	0.06	34.5	0.06	34.5	
37 HOBBIES AND CRAFTS	1.20	5.52	4.89	8.4	0.04	0.07	0.80	0.90	0.15	317.7	0.15	317.7	
38 PERSONAL LETTERS	0.66	3.31	2.79	4.3	0.02	0.04	0.45	0.52	0.08	182.4	0.08	182.4	
TOTAL	1440.00	1440.00	1440.00	4058.7	50.07	17.22	234.24	301.53	71.47	105767.8	71.47	105767.8	

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE UNDER \$5000 HOUSEHOLD INCOME CLASS

	TOTAL EXPENSE BILLION \$	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1 JOB	20.089	6	0.0000	--	----	--
2 TRAVEL TO JOB	5.2041	14	4.5301	6	0.5225	30
3 FOOD PREPARATION	41.3153	2	1.4052	19	2.1034	16
4 HOUSE CLEANING	12.9937	9	0.1166	33	25.3034	2
5 GARDENING	0.8931	30	2.8445	10	1.0312	23
6 PET CARE	0.8243	31	4.4425	7	0.6596	28
7 CLOTHING AND LINENS	14.6975	8	1.9013	15	1.5543	20
8 HOUSE	22.2319	4	29.9685	2	0.0969	33
9 MEDICAL CARE GIVEN	0.6451	29	14.7593	3	0.1965	32
10 CHILD CARE	17.5764	7	0.1576	32	19.0925	3
11 FINANCIAL MANAGEMENT	7.5902	13	1.7299	16	1.6419	19
12 TRAVEL/FRO MEDICAL	0.2942	35	5.5035	5	0.5230	29
13 TRAVEL/EDUCATION	0.2137	36	2.3620	14	1.2136	21
14 TRAVEL/ORG & RELIGION	1.0731	25	2.5991	13	1.0970	22
15 TRAVEL/SOCAL LIFE	3.0343	20	2.7718	11	1.0147	24
16 TRAVEL/LEISURE	0.5049	33	2.9555	9	0.9365	25
17 SHOPPING/NON-TRADABLE	2.5164	21	1.4195	18	2.0305	17
TOTAL--TRADABLE	151.9869		1.4690		1.9165	
18 PERSONAL CARE PHONE	11.3747	10	0.1677	31	16.5773	4
19 PERSONAL CARE SERVICES	1.0412	27	7.2951	4	0.3832	31
20 MED CARE RECEIVE PHONE	0.0691	38	0.0000	--	-----	--
21 FRO MEDICAL CARE	4.6306	17	45.7402	1	0.0635	34
22 EATING AT HOME	10.5270	11	0.0000	--	-----	--
23 EATING OUT	4.9121	15	3.5092	8	0.7352	26
24 SLEEP AND REST	109.0776	1	0.0000	--	-----	--
25 VACATION	4.6530	16	1.0576	22	2.6711	13
26 EDUCATION	1.0910	24	0.7736	24	3.1240	12
27 RELIGION	3.2928	19	1.1594	20	2.4717	15
28 OTHER ORGANIZATIONS	0.4454	34	2.7349	12	0.6652	27
29 TELEVISION	29.1837	3	0.0547	34	53.3922	1
30 READING	4.1008	18	0.2498	30	11.1827	5
31 SOCIAL LIFE	21.5510	5	0.6504	26	4.5147	9
32 CONVERSATION	8.4444	12	0.8413	23	3.4747	10
33 OUTDOORS	2.1961	22	0.6305	27	4.7247	8
34 ENTERTAINMENT	0.9766	28	0.6950	25	3.2402	11
35 LISTENING TO SOUNDS	1.6317	23	1.1223	21	2.5170	14
36 PERFORMING	0.1552	37	1.6315	17	1.8069	18
37 HOBBIES AND CRAFTS	1.0518	26	0.4659	28	6.0899	7
38 PERSONAL LETTERS	0.5934	32	0.4166	29	6.7714	6
TOTAL	373.0007		0.6750		4.2187	

ASSUMPTIONS ABOUT THE THE UNDER \$5000 HOUSEHOLD INCOME CLASS

	WAGE RATE (\$/HOUR AFTER TAX)	POPULATION (MILLIONS)
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EMPLOYED MEN	2.76	2.07
EMPLOYED WOMEN	1.52	1.29
HOUSEHIVES	3.07	8.71

TOTAL NUMBER OF HOUSEHOLDS	17.61 MILLION
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VALUE OF TIME VS. MARKET EXPENDITURES FOR THE \$5000-7999 HOUSEHOLD INCOME CLASS

ACTIVITY	MINUTES/DAY				1973 \$/HOUSE-				BILLION 1973 \$			
	EMPLOYED MEN	EMPLOYED WOMEN	HOUSE- WIVES	HOLD MARKET EXPEND-ITURES	EMPLOYED MEN VALUE OF TIME	EMPLOYED WOMEN VALUE OF TIME	HOUSE- WIVES VALUE OF TIME	TOTAL VALUE OF TIME	TOTAL MARKET EXPEND-ITURES	PERSON HOURS (MIL- LIONS)		
1 JOB	365.94	294.95	3.12	0.0	33.35	9.25	0.29	42.88	0.00	14713.2		
2 TRAVEL TO JOB	32.70	23.63	0.53	383.2	2.98	0.74	0.05	3.77	4.02	1277.6		
3 FOOD PREPARATION	25.64	84.76	167.27	1108.4	2.34	2.66	15.53	20.52	11.63	7350.2		
4 HOUSE CLEANING	6.71	42.47	83.68	35.2	0.61	1.33	7.77	9.71	0.37	3524.8		
5 GARDENING	1.63	0.87	1.65	33.5	0.15	0.03	0.15	0.33	0.35	109.8		
6 PET CARE	1.19	0.70	1.21	48.6	0.11	0.02	0.11	0.24	0.51	81.3		
7 CLOTHING AND LINENS	7.31	33.50	65.63	585.0	0.67	1.05	6.09	7.81	6.15	2822.1		
8 HOUSE	13.30	7.65	10.54	1565.1	1.21	0.24	0.98	2.43	16.42	813.2		
9 MEDICAL CARE GIVEN	0.52	0.62	0.63	69.6	0.05	0.02	0.08	0.14	0.73	50.3		
10 CHILD CARE	10.24	21.27	60.70	99.1	0.93	0.67	5.63	7.23	1.04	2541.2		
11 FINANCIAL MANAGEMENT	19.38	42.53	39.11	420.1	1.77	1.33	3.63	6.73	4.41	2455.1		
12 TRAVEL/PRO MEDICAL	0.45	0.51	0.32	21.7	0.04	0.02	0.03	0.09	0.23	30.4		
13 TRAVEL/EDUCATION	0.61	0.45	0.70	10.6	0.05	0.01	0.06	0.14	0.11	45.9		
14 TRAVEL/ORG & RELIGION	2.46	2.72	3.50	57.4	0.22	0.09	0.32	0.63	0.60	220.9		
15 TRAVEL/SOCAL LIFE	7.37	9.05	9.10	168.9	0.67	0.28	0.84	1.80	1.77	633.5		
16 TRAVEL/LEISURE	1.23	1.81	1.40	29.2	0.11	0.06	0.13	0.30	0.31	105.9		
17 SHOPPING/NON-TRADABLE	5.89	8.25	7.11	93.1	0.54	0.26	0.66	1.46	0.98	517.9		
TOTAL--TRADABLE	502.57	575.74	456.41	4729.9	45.79	18.05	42.37	106.21	40.62	37312.4		
18 PERSONAL CARE PHONE	50.21	72.57	69.67	59.1	4.58	2.28	6.47	13.32	0.62	4737.4		
19 PERSONAL CARE SERVICES	0.08	1.96	2.02	48.5	0.08	0.06	0.19	0.33	0.51	119.7		
20 MED CARE RECEIVE PHONE	0.22	0.25	0.50	0.0	0.02	0.01	0.05	0.07	0.00	25.9		
21 PRO MEDICAL CARE	0.98	0.98	2.02	387.8	0.08	0.03	0.19	0.30	4.07	103.4		
22 EATING AT HOME	64.11	43.83	70.41	0.0	5.84	1.37	6.54	13.75	0.00	4653.3		
23 EATING OUT	35.99	21.91	5.95	290.5	3.28	0.69	0.55	4.52	3.05	1507.5		
24 SLEEP AND REST	462.47	455.50	477.83	0.0	42.14	14.28	44.35	100.78	0.00	34928.8		
25 VACATION	30.47	30.53	30.65	126.7	2.78	0.96	2.85	6.58	1.33	2283.6		
26 EDUCATION	2.98	4.55	0.00	25.4	0.27	0.14	0.00	0.41	0.27	154.7		
27 RELIGION	6.55	10.36	11.50	94.0	0.60	0.32	1.07	1.99	0.99	709.1		
28 OTHER ORGANIZATIONS	4.69	2.10	2.67	17.8	0.43	0.07	0.25	0.74	0.19	243.8		
29 TELEVISION	130.87	59.60	116.67	54.2	11.93	1.87	10.83	24.62	0.57	8149.0		
30 READING	25.69	24.06	36.34	32.1	2.34	0.75	3.37	6.47	0.34	2229.0		
31 SOCIAL LIFE	64.22	89.48	88.94	389.1	5.85	2.81	8.26	16.91	4.08	5995.6		
32 CONVERSATION	11.12	14.88	26.18	154.8	1.01	0.47	2.43	3.91	1.62	1368.9		
33 OUTDOORS	14.21	2.77	2.07	51.6	1.30	0.09	0.19	1.57	0.54	489.9		
34 ENTERTAINMENT	22.94	10.66	10.30	33.2	2.09	0.33	0.96	3.38	0.35	1111.6		
35 LISTENING TO MUSIC	4.13	6.90	6.08	44.3	0.38	0.22	0.56	1.16	0.47	416.1		
36 PERFORMING	0.50	0.34	1.61	6.3	0.05	0.01	0.15	0.21	0.07	70.0		
37 HOBBIES AND CRAFTS	2.77	6.89	14.10	15.8	0.25	0.22	1.31	1.78	0.17	633.2		
38 PERSONAL LETTERS	1.51	4.13	8.06	7.2	0.14	0.13	0.75	1.02	0.08	363.2		
TOTAL	1440.00	1440.00	1440.00	6568.7	131.21	45.15	133.67	310.03	68.91	107607.4		

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE \$5000-7999 HOUSEHOLD INCOME CLASS

	TOTAL EXPENSE BILLION \$	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1 JOB	42.6329	2	0.0000	--	----	--
2 TRAVEL TO JOB	7.7904	14	3.1460	8	0.9370	27
3 FOOD PREPARATION	32.1470	3	1.5780	16	1.7648	17
4 HOUSE CLEANING	10.0801	11	0.1049	33	26.2702	2
5 GARDENING	0.6803	33	3.2024	7	0.9353	28
6 PET CARE	0.7517	31	6.2641	5	0.4755	30
7 CLOTHING AND LINENS	13.9556	7	2.1781	13	1.2703	22
8 HOUSE	16.8483	6	20.1899	2	0.1491	33
9 MEDICAL CARE GIVEN	0.8739	29	14.5055	3	0.1971	32
10 CHILD CARE	8.2732	12	0.4089	27	6.9613	8
11 FINANCIAL MANAGEMENT	11.1364	10	1.7950	16	1.5270	19
12 TRAVEL/PRO MEDICAL	0.3136	35	7.4620	4	0.3807	31
13 TRAVEL/EDUCATION	0.2487	37	2.4711	12	1.1907	23
14 TRAVEL/ORG & RELIGION	1.2360	26	2.7249	11	1.0535	24
15 TRAVEL/SOCAL LIFE	3.5724	20	2.7868	10	1.0164	25
16 TRAVEL/LEISURE	0.6054	34	2.8680	9	0.9744	26
17 SHOPPING/NON-TRADABLE	2.4323	22	1.8859	15	1.4902	20
TOTAL--TRADABLE	155.8280		1.3298		2.1407	
18 PERSONAL CARE SHOME	13.9375	8	0.1308	32	21.4839	3
19 PERSONAL CARE SERVICES	0.8378	30	4.2489	6	0.6473	29
20 MED CARE RECEIVE SHOME	0.0746	38	0.0000	--	----	--
21 PRO MEDICAL CARE	4.3663	18	39.3300	1	0.0731	34
22 EATING AT HOME	13.7516	9	0.0000	--	----	--
23 EATING OUT	7.5664	15	2.0215	14	1.4620	21
24 SLEEP AND REST	100.7766	1	0.0000	--	----	--
25 VACATION	7.9080	13	0.5832	26	4.9481	9
26 EDUCATION	0.6803	32	1.7203	17	1.5556	18
27 RELIGION	2.9759	21	1.3911	19	2.0171	16
28 OTHER ORGANIZATIONS	0.9285	28	0.7674	24	3.9621	11
29 TELEVISION	25.1918	4	0.0697	34	43.3383	1
30 READING	6.8059	16	0.1512	31	19.1868	4
31 SOCIAL LIFE	20.9546	5	0.4804	25	4.1439	10
32 CONVERSATION	5.5340	17	1.1862	20	2.4079	15
33 OUTDOORS	2.1152	23	1.1069	22	2.9037	13
34 ENTERTAINMENT	3.7293	19	0.3133	28	9.7074	7
35 LISTENING TO SOUNDS	1.6259	25	1.1255	21	2.4614	14
36 PERFORMING	0.2720	35	0.9369	23	3.1397	12
37 HOBBIES AND CRAFTS	1.9434	24	0.2619	29	10.7215	6
38 PERSONAL LETTERS	1.0910	27	0.2082	30	13.4320	5
TOTAL	378.9343		0.6403		4.4993	

ASSUMPTIONS ABOUT THE THE \$5000-7999 HOUSEHOLD INCOME CLASS

	WAGE RATE (\$/HOUR AFTER TAX)	POPULATION (MILLIONS)
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EMPLOYED MEN	3.43	4.37
EMPLOYED WOMEN	1.89	2.73
HOUSEHIVES	2.94	5.19

TOTAL NUMBER OF HOUSEHOLDS	10.49 MILLION
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VALUE OF TIME VS. MARKET EXPENDITURES FOR THE \$8000-9999 HOUSEHOLD INCOME CLASS

ACTIVITY	MINUTES/DAY				1973 \$/HOUSEHOLD				BILLION 1973 \$			
	EMPLOYED MEN	EMPLOYED WOMEN	HOUSEHOLD	HOUSEHOLD	EMPLOYED MEN	EMPLOYED WOMEN	HOUSEHOLD	HOUSEHOLD	EMPLOYED MEN	EMPLOYED WOMEN	HOUSEHOLD	HOUSEHOLD
					VALUE OF TIME	VALUE OF TIME	VALUE OF TIME	VALUE OF TIME	VALUE OF TIME	VALUE OF TIME	VALUE OF TIME	VALUE OF TIME
1 JOB	391.63	268.20	2.64	0.0	38.65	9.09	0.16	47.89	0.00	15005.2		
2 TRAVEL TO JOB	39.36	27.37	0.35	505.5	3.88	0.93	0.02	4.83	3.52	1516.8		
3 FOOD PREPARATION	23.07	84.88	157.98	1284.5	2.28	2.88	9.39	14.54	8.94	5339.7		
4 HOUSE CLEANING	8.19	37.36	81.45	47.0	0.81	1.27	4.84	6.91	0.33	2546.6		
5 GARDENING	1.27	2.04	2.72	37.9	0.13	0.07	0.16	0.26	0.26	124.9		
6 PET CARE	0.95	1.51	1.96	61.9	0.09	0.05	0.12	0.26	0.43	91.6		
7 CLOTHING AND LINENS	9.76	45.85	66.74	739.1	0.96	1.55	3.97	6.48	5.14	2422.8		
8 HOUSE	10.77	8.27	12.77	1834.4	1.06	0.28	0.76	2.10	12.77	693.2		
9 MEDICAL CARE GIVEN	0.59	0.71	0.87	80.6	0.06	0.02	0.05	0.13	0.56	45.6		
10 CHILD CARE	6.40	21.76	82.77	134.1	0.63	0.74	4.92	6.29	0.93	2266.3		
11 FINANCIAL MANAGEMENT	14.29	38.33	43.80	702.7	1.41	1.30	2.60	5.31	4.89	1935.2		
12 TRAVEL/FRO MEDICAL	0.37	0.61	0.56	28.5	0.04	0.02	0.03	0.09	0.20	31.9		
13 TRAVEL/EDUCATION	0.80	0.31	0.67	14.3	0.08	0.01	0.04	0.13	0.10	40.5		
14 TRAVEL/ORG C RELIGION	3.21	1.85	3.33	75.7	0.32	0.26	0.20	0.66	0.53	186.4		
15 TRAVEL/SOCAL LIFE	9.62	6.17	8.67	222.8	0.95	0.21	0.52	1.67	1.55	541.7		
16 TRAVEL/LEISURE	1.60	1.23	1.33	38.6	0.16	0.04	0.09	0.29	0.27	91.4		
17 SHOPPING/HIGH-TRADABLE	6.24	9.72	8.50	122.8	0.62	0.33	0.51	1.45	0.05	507.0		
TOTAL--TRADABLE	528.08	556.16	477.11	5930.6	52.11	18.05	28.36	99.31	41.28	33390.1		
18 PERSONAL CARE PHONE	63.33	71.25	60.42	71.0	6.25	2.41	3.59	12.25	0.49	4147.2		
19 PERSONAL CARE SERVICES	1.11	1.93	1.75	78.9	0.11	0.07	0.10	0.20	0.55	98.5		
20 MED CARE RECEIVE PHONE	0.28	0.24	0.44	0.0	0.03	0.01	0.03	0.06	0.00	20.6		
21 PRO MEDICAL CARE	1.11	0.96	1.75	450.0	0.11	0.03	0.10	0.25	3.19	82.4		
22 EATING AT HOME	54.79	49.74	75.17	0.0	5.41	1.69	4.47	11.56	0.00	3956.5		
23 EATING OUT	30.76	24.87	6.35	374.7	3.04	0.84	0.38	4.26	2.61	1370.6		
24 SLEEP AND REST	459.44	470.32	476.65	0.0	45.34	15.94	28.33	99.60	0.00	30112.0		
25 VACATION	33.83	33.76	33.95	176.5	3.34	1.14	2.02	6.50	1.23	2178.8		
26 EDUCATION	4.90	0.96	0.60	42.9	0.48	0.03	0.04	0.55	0.30	159.6		
27 RELIGION	8.75	4.29	14.63	117.1	0.86	0.15	0.87	1.88	0.82	611.9		
28 OTHER ORGANIZATIONS	5.38	6.44	11.99	27.2	0.53	0.22	0.71	1.46	0.19	502.3		
29 TELEVISION	95.88	67.43	101.26	64.3	9.46	2.29	6.02	17.76	0.45	5928.6		
30 READING	30.62	24.76	31.84	41.0	3.02	0.84	1.89	5.75	0.29	1898.6		
31 SOCIAL LIFE	81.40	66.20	83.06	479.3	8.03	2.24	4.94	15.21	3.34	5020.2		
32 CONVERSATION	8.95	13.95	23.10	172.2	0.88	0.47	1.37	2.73	1.20	955.8		
33 OUTDOORS	12.42	10.11	9.24	69.3	1.23	0.34	0.55	2.12	0.62	634.4		
34 ENTERTAINMENT	7.61	4.39	4.68	36.6	0.75	0.15	0.28	1.18	0.25	374.6		
35 LISTENING TO SOUNDS	5.13	5.06	2.50	54.7	0.51	0.17	0.15	0.83	0.39	274.0		
36 PERFORMING	0.66	0.82	1.59	11.9	0.06	0.03	0.09	0.19	0.08	64.6		
37 HOBBIES AND CRAFTS	3.60	16.47	13.95	26.4	0.36	0.55	0.63	1.74	0.13	663.1		
38 PERSONAL LETTERS	1.97	9.88	7.97	8.0	0.19	0.33	0.47	1.00	0.06	384.3		
TOTAL	1440.00	1440.00	1440.00	8260.5	142.10	48.80	85.58	276.47	57.49	92680.4		

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE \$6000-9999 HOUSEHOLD INCOME CLASS

	TOTAL EXPENSE BILLION \$	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1 JOB	47.6905	2	0.0000	--	---	--
2 TRAVEL TO JOB	9.3508	11	2.3196	12	1.3734	21
3 FOOD PREPARATION	23.4519	3	1.6743	18	1.6265	20
4 HOUSE CLEANING	7.2409	13	0.1285	32	21.1262	3
5 GARDENING	0.6197	33	2.1102	14	1.3509	22
6 PET CARE	0.6923	32	4.7047	6	0.6062	29
7 CLOTHING AND LINENS	11.6270	8	2.1233	13	1.2601	24
8 HOUSE	14.8595	6	18.4171	2	0.1646	33
9 MEDICAL CARE GIVEN	0.6945	31	12.3116	3	0.2373	32
10 CHILD CARE	7.2212	14	0.4120	27	6.7316	8
11 FINANCIAL MANAGEMENT	10.2013	10	2.5233	10	1.0959	26
12 TRAVEL/PRO MEDICAL	0.2895	35	6.2237	4	0.4574	31
13 TRAVEL/EDUCATION	0.2266	37	2.4517	11	1.2996	23
14 TRAVEL/ORG & RELIGION	1.1042	27	2.8253	9	1.0959	25
15 TRAVEL/SOCAL LIFE	3.2242	19	2.8625	8	1.0794	27
16 TRAVEL/LEISURE	0.5477	34	2.9386	7	1.0408	29
17 SHOPPING/NON-TRADABLE	2.3050	22	1.6859	17	1.6966	18
TOTAL--TRADABLE	140.5997		1.2362		2.4060	
18 PERSONAL CARE INCOME	12.7479	7	0.1191	33	24.8103	2
19 PERSONAL CARE SERVICES	0.8279	30	5.5728	5	0.5032	30
20 MED CARE RECEIVE INCOME	0.0616	39	0.0000	--	---	--
21 PRO MEDICAL CARE	3.4339	18	39.6705	1	0.0773	34
22 EATING AT HOME	11.5595	9	0.0000	--	---	--
23 EATING OUT	6.6633	15	1.9026	15	1.6319	19
24 SLEEP AND REST	89.6023	1	0.0000	--	---	--
25 VACATION	7.7281	12	0.5640	26	5.2903	9
26 EDUCATION	0.6502	29	1.8708	16	1.8477	17
27 RELIGION	2.6939	21	1.3322	20	2.3047	13
28 OTHER ORGANIZATIONS	1.6510	24	0.3763	28	7.7235	7
29 TELEVISION	18.2118	5	0.0771	34	39.6723	1
30 READING	6.0383	16	0.1501	30	20.1837	4
31 SOCIAL LIFE	18.5488	4	0.6645	25	4.5501	11
32 CONVERSATION	3.9275	17	1.2538	22	2.2775	14
33 OUTDOORS	2.7392	20	0.8943	23	3.4083	12
34 ENTERTAINMENT	1.4323	25	0.6503	24	4.6197	10
35 LISTENING TO SOUNDS	1.2075	26	1.3904	19	2.1693	16
36 PERFORMING	0.2701	35	1.2818	21	2.2611	15
37 HOBBIES AND CRAFTS	1.9262	23	0.2770	29	9.4871	6
38 PERSONAL LETTERS	1.0583	28	0.1453	31	17.9538	5
TOTAL	333.9603		0.6203		4.8088	

ASSUMPTIONS ABOUT THE THE \$6000-9999 HOUSEHOLD INCOME CLASS

	WAGE RATE (\$/HOUR AFTER TAX)	POPULATION (MILLIONS)
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EMPLOYED MEN	3.69	4.40
EMPLOYED WOMEN	2.03	2.74
HOUSEHIVES	2.84	3.44

TOTAL NUMBER OF HOUSEHOLDS	6.96 MILLION
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VALUE OF TIME VS. MARKET EXPENDITURES FOR THE \$10,000-11,999 HOUSEHOLD INCOME CLASS

ACTIVITY	MINUTES/DAY				1973				BILLION 1973 \$			
	EMPLOYED MEN	EMPLOYED WOMEN	HOUSE- HIVES	HOUSE- HOLD	EMPLOYED MEN	EMPLOYED WOMEN	HOUSE- HIVES	HOUSE- HOLD	EMPLOYED MEN	EMPLOYED WOMEN	HOUSE- HIVES	HOUSE- HOLD
					MARKET EXPEND- ITURES	VALUE OF TIME	OF TIME	OF TIME	MARKET EXPEND- ITURES	VALUE OF TIME	OF TIME	OF TIME
1 JOB	400.67	309.90	0.00	0.00	49.74	13.23	0.00	62.97	0.00	62.97	0.00	1921.5
2 TRAVEL TO JOB	40.25	27.15	0.00	617.0	5.00	1.16	0.00	6.16	4.09	6.16	4.09	1938.8
3 FOOD PREPARATION	23.21	99.87	147.93	1393.9	2.89	4.26	8.24	15.38	9.24	15.38	9.24	5791.9
4 HOUSE CLEANING	6.84	45.06	74.85	50.1	0.85	1.92	4.17	6.94	0.33	6.94	0.33	2654.7
5 GARDENING	2.40	1.80	5.55	46.5	0.30	0.08	0.31	227.6	0.31	0.08	0.31	161.3
6 PET CARE	1.73	1.32	3.64	70.7	0.21	0.06	0.21	0.48	0.47	0.48	0.47	161.3
7 CLOTHING AND LINENS	7.15	45.96	69.81	862.4	0.89	1.96	3.89	6.74	5.72	6.74	5.72	2532.8
8 HOUSE	15.50	6.74	10.29	1933.5	1.92	0.29	0.57	2.78	13.15	2.78	13.15	839.2
9 MEDICAL CARE GIVEN	0.62	0.61	0.94	75.8	0.08	0.03	0.05	0.16	0.50	0.16	0.50	52.1
10 CHILD CARE	9.67	28.96	80.22	157.6	1.20	1.24	4.47	6.90	1.04	6.90	1.04	2521.8
11 FINANCIAL MANAGEMENT	23.70	26.35	36.03	919.1	2.94	1.12	2.01	6.07	6.09	6.07	6.09	2051.7
12 TRAVEL/PRO MEDICAL	0.52	0.53	0.57	34.9	0.07	0.02	0.03	0.12	0.23	0.12	0.23	39.7
13 TRAVEL/EDUCATION	0.62	0.35	0.72	17.4	0.10	0.01	0.04	0.16	0.12	0.16	0.12	48.7
14 TRAVEL/ORG & RELIGION	3.29	2.07	3.59	92.4	0.41	0.09	0.20	0.70	0.61	0.70	0.61	223.5
15 TRAVEL/SOCIAL LIFE	9.86	6.90	9.32	271.9	1.22	0.29	0.52	2.04	1.80	2.04	1.80	656.1
16 TRAVEL/LEISURE	1.64	1.39	1.43	47.1	0.20	0.06	0.08	0.34	0.31	0.34	0.31	111.7
17 SHOPPING/NON-TRADABLE	7.91	7.28	8.06	149.9	0.98	0.31	0.45	1.74	0.99	1.74	0.99	574.3
TOTAL--TRADABLE	555.79	612.22	453.13	6700.0	68.99	26.14	25.23	120.36	45.02	120.36	45.02	40177.5
18 PERSONAL CARE HOME	55.25	70.23	72.73	85.3	6.86	3.00	4.05	13.91	0.57	13.91	0.57	4730.7
19 PERSONAL CARE SERVICES	0.97	1.90	2.11	93.2	0.12	0.08	0.12	0.32	0.62	0.32	0.62	113.6
20 MED CARE RECEIVE HOME	0.24	0.24	0.53	0.0	0.03	0.01	0.03	0.07	0.00	0.07	0.00	23.5
21 PRO MEDICAL CARE	0.97	0.95	2.11	488.8	0.12	0.04	0.12	0.28	3.24	0.28	3.24	93.9
22 EATING AT HOME	53.02	44.25	65.45	0.0	6.58	1.99	3.81	12.28	0.00	12.28	0.00	4042.9
23 EATING OUT	29.77	22.12	5.78	444.6	3.70	0.94	0.32	4.96	2.95	4.96	2.95	1562.0
24 SLEEP AND REST	450.28	479.97	488.79	0.0	55.90	20.49	27.21	103.60	0.00	103.60	0.00	34646.1
25 VACATION	27.74	27.74	27.66	214.2	3.44	1.18	1.54	6.17	1.42	6.17	1.42	2047.3
26 EDUCATION	13.14	2.50	1.40	65.4	1.63	0.11	0.08	1.82	0.43	1.82	0.43	515.9
27 RELIGION	8.11	9.25	14.36	139.9	1.01	0.39	0.80	2.20	0.92	2.20	0.92	747.0
28 OTHER ORGANIZATIONS	9.08	0.35	6.73	37.4	1.13	0.02	0.37	1.52	0.25	1.52	0.25	443.2
29 TELEVISION	101.72	45.45	100.11	66.1	12.63	1.94	5.57	20.14	0.44	20.14	0.44	6315.6
30 READING	34.70	20.02	39.04	45.3	4.31	0.85	2.17	7.34	0.30	7.34	0.30	2345.6
31 SOCIAL LIFE	54.00	54.88	63.58	498.1	6.70	2.34	4.65	13.70	3.29	13.70	3.29	4597.5
32 CONVERSATION	14.51	23.87	32.77	184.0	1.80	1.02	1.82	4.64	1.22	4.64	1.22	1630.2
33 OUTDOORS	10.77	6.62	2.51	118.5	1.34	0.28	0.14	1.76	0.79	1.76	0.79	544.8
34 ENTERTAINMENT	4.19	4.63	6.18	49.6	0.52	0.20	0.34	1.06	0.33	1.06	0.33	358.4
35 LISTENING TO SOUNDS	5.35	2.39	2.48	59.1	0.66	0.10	0.14	0.90	0.39	0.90	0.39	276.6
36 PERFORMING	1.09	0.32	2.00	12.1	0.14	0.01	0.11	0.26	0.09	0.26	0.09	82.8
37 HOBBIES AND CRAFTS	6.02	6.32	17.51	31.8	0.75	0.27	0.97	1.99	0.21	1.99	0.21	680.2
38 PERSONAL LETTERS	3.28	3.79	10.01	8.8	0.41	0.16	0.56	1.13	0.06	1.13	0.06	387.2
TOTAL	1440.00	1440.00	1440.00	9428.8	170.75	61.48	80.16	320.40	62.51	320.40	62.51	106372.3

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE \$10,000-11,999 HOUSEHOLD INCOME CLASS

	TOTAL EXPENSE BILLION \$	RANK	MARKET EXPENDITURES PER HOUR	RANK	PATIO TIME VALUE/ MARKET EXPENDITURES	PARK
1 JOB	62.9678	2	0.0000	--	----	--
2 TRAVEL TO JOB	10.2470	11	2.1543	13	1.5049	22
3 FOOD PREPARATION	24.5222	3	1.5936	16	1.6642	21
4 HOUSE CLEANING	7.2726	16	0.1250	32	20.9141	4
5 GARDENING	0.9020	30	1.3516	19	2.2172	18
6 PET CARE	0.9330	31	2.5041	7	1.0344	28
7 CLOTHING AND LINENS	12.4535	8	2.2137	12	1.1761	24
8 HOUSE	15.9141	6	15.3060	2	0.2117	33
9 MEDICAL CARE GIVEN	0.6589	33	9.6433	3	0.3100	32
10 CHILD CARE	7.5477	12	0.4144	28	6.6056	7
11 FINANCIAL MANAGEMENT	12.1650	10	2.9700	6	0.9965	29
12 TRAVEL/PRO MEDICAL	0.3504	35	5.8216	4	0.5162	30
13 TRAVEL/EDUCATION	0.2721	37	2.3718	11	1.3553	23
14 TRAVEL/ORG & RELIGION	1.5032	27	2.7405	10	1.1351	25
15 TRAVEL/SOCIAL LIFE	3.8396	18	2.7475	9	1.1299	26
16 TRAVEL/LEISURE	0.6547	34	2.7925	8	1.0932	27
17 SHOPPING/NOV-TRADABLE	2.7355	21	1.7305	15	1.7525	19
TOTAL--TRADABLE	165.3750		1.1205		2.6735	
18 PERSONAL CARE ENGINE	14.4714	7	0.1193	33	24.5246	2
19 PERSONAL CARE SERVICES	0.9369	32	5.4423	5	0.5156	31
20 MED CARE RECEIVE ENGINE	0.0696	38	0.0020	--	-----	--
21 PRO MEDICAL CARE	3.5187	19	34.5064	1	0.0859	34
22 EATING AT HOME	12.0620	9	0.0020	--	-----	--
23 EATING OUT	7.5092	13	1.8970	14	1.6335	20
24 SLEEP AND REST	103.5896	1	0.0020	--	-----	--
25 VACATION	7.5671	15	0.6937	26	4.3421	9
26 EDUCATION	2.2493	23	0.8402	23	4.1893	10
27 RELIGION	3.1216	20	1.2317	20	2.3909	15
28 OTHER ORGANIZATIONS	1.7653	25	0.5590	27	6.1250	8
29 TELEVISION	20.5794	4	0.0594	34	45.9413	1
30 READING	7.6356	14	0.1220	31	24.4362	3
31 SOCIAL LIFE	16.9234	5	0.7154	25	4.1653	11
32 CONVERSATION	5.8642	17	0.7482	24	3.8077	12
33 OUTDOORS	2.5450	22	1.4423	17	2.2389	17
34 ENTERTAINMENT	1.3908	26	0.9169	22	3.2322	14
35 LISTENING TO SOUNDS	1.2957	28	1.4159	13	2.3067	16
36 PERFORMING	0.3408	36	0.5655	21	3.2616	13
37 HOBBIES AND CRAFTS	2.0228	24	0.3098	29	9.4541	6
38 PERSONAL LETTERS	1.1250	29	0.1507	30	19.3017	5
TOTAL	392.9089		0.5877		5.1252	

ASSUMPTIONS ABOUT THE THE \$10,000-11,999 HOUSEHOLD INCOME CLASS

	WAGE RATE (\$/HOUR AFTER TAX)	POPULATION (MILLIONS)
EMPLOYED MEN	3.74	5.46
EMPLOYED WOMEN	2.06	3.41
HOUSEWIVES	2.79	3.28

TOTAL NUMBER OF HOUSEHOLDS 6.63 MILLION

VALUE OF TIME VS. MARKET EXPENDITURES FOR THE \$12,000-19,999 HOUSEHOLD INCOME CLASS

ACTIVITY	MINUTES/DAY			1973 \$/HOUSE-			BILLION 1973 \$				PERSON HOURS (MILLIONS)
	EMPLOYED MEN	EMPLOYED WOMEN	HOUSE- WIVES	EMPLOYED MEN	EMPLOYED WOMEN	HOUSE- WIVES	EMPLOYED MEN	EMPLOYED WOMEN	HOUSE- WIVES	TOTAL MARKET EXPENDITURES	
1 JOB	391.26	325.40	10.42	0.0	0.0	0.0	203.64	58.02	1.66	263.32	77763.0
2 TRAVEL TO JOB	38.09	31.29	0.36	759.4	759.4	0.06	19.82	5.58	0.06	25.46	7500.5
3 FOOD PREPARATION	26.68	84.73	152.17	1678.4	1678.4	15.11	13.89	15.11	24.24	53.23	19207.1
4 HOUSE CLEANING	8.21	41.84	74.00	65.0	65.0	7.46	4.27	7.46	11.79	23.51	8772.3
5 GARDENING	1.32	2.06	3.12	67.5	67.5	0.37	0.69	0.37	0.50	1.55	520.8
6 PET CARE	1.02	1.52	2.23	97.4	97.4	0.27	0.53	0.27	0.36	1.16	385.4
7 CLOTHING AND LINENS	7.56	20.14	75.77	1093.1	1093.1	3.59	3.93	3.59	12.07	19.59	7032.7
8 HOUSE	18.81	6.20	10.48	2415.5	2415.5	1.11	9.79	1.11	1.67	12.57	3553.5
9 MEDICAL CARE GIVEN	0.65	0.65	0.93	100.4	100.4	0.12	0.34	0.12	0.15	0.60	191.2
10 CHILD CARE	0.69	19.29	69.52	197.4	197.4	3.44	4.52	3.44	11.07	19.03	6746.1
11 FINANCIAL MANAGEMENT	20.17	23.07	36.90	1304.8	1304.8	4.11	10.50	4.11	5.88	20.49	6640.9
12 TRAVEL/PRO MEDICAL	0.60	0.50	0.57	42.9	42.9	0.09	0.31	0.09	0.09	0.49	151.1
13 TRAVEL/EDUCATION	0.79	0.46	0.83	21.5	21.5	0.05	0.41	0.05	0.13	0.62	187.5
14 TRAVEL/ORG & RELIGION	3.14	2.77	4.13	113.7	113.7	0.49	1.64	0.49	0.66	2.79	872.9
15 TRAVEL/SOCIAL LIFE	9.43	9.23	10.73	334.7	334.7	1.65	4.91	1.65	1.71	8.26	2597.3
16 TRAVEL/LEISURE	1.57	1.85	1.65	57.9	57.9	0.82	0.82	0.33	0.26	1.41	449.8
17 SHOPPING/NON-TRADABLE	7.69	8.87	9.06	184.5	184.5	1.58	4.00	1.58	1.44	7.03	2245.3
TOTAL--TRADABLE	545.66	579.84	462.67	8524.0	8524.0	103.38	284.00	103.38	73.72	461.10	144019.0
18 PERSONAL CARE 2/HOME	54.51	64.21	66.10	102.0	102.0	1.45	28.37	11.45	10.53	50.35	16135.3
19 PERSONAL CARE SERVICES	0.96	1.74	1.92	113.6	113.6	0.31	0.50	0.31	0.31	1.11	376.5
20 MED CARE RECEIVE 2/HOME	0.24	0.22	0.48	0.0	0.0	0.04	0.12	0.04	0.08	0.24	76.6
21 PRO MEDICAL CARE	0.96	0.87	1.92	569.2	569.2	0.15	0.50	0.15	0.31	0.95	306.2
22 EATING AT HOME	60.81	48.93	70.09	0.0	0.0	8.72	31.65	8.72	11.16	51.53	15946.4
23 EATING OUT	34.14	24.46	5.92	538.8	538.8	4.36	17.77	4.36	0.94	23.07	6758.9
24 SLEEP AND REST	456.58	464.67	473.56	0.0	0.0	82.85	237.64	82.85	75.42	395.91	124546.4
25 VACATION	23.17	23.09	23.07	319.5	319.5	4.12	12.06	4.12	3.67	19.85	6224.7
26 EDUCATION	5.55	4.46	10.38	119.8	119.8	0.80	2.89	0.80	1.65	5.34	1687.1
27 RELIGION	4.55	2.53	15.84	195.5	195.5	0.45	2.37	0.45	2.52	5.34	1719.1
28 OTHER ORGANIZATIONS	6.83	2.18	19.18	58.2	58.2	0.39	3.56	0.39	3.05	7.00	2182.5
29 TELEVISION	85.00	57.76	74.03	78.9	78.9	10.30	44.24	10.30	11.79	66.33	20032.2
30 READING	43.10	30.94	33.45	60.2	60.2	5.52	22.43	5.52	5.33	33.28	10053.8
31 SOCIAL LIFE	49.58	73.06	97.11	621.8	621.8	13.03	25.80	13.03	15.47	54.30	18020.9
32 CONVERSATION	13.33	13.57	31.12	210.6	210.6	2.42	6.94	2.42	4.96	14.31	4645.6
33 OUTDOORS	16.49	9.57	1.09	199.5	199.5	1.71	8.58	1.71	0.17	10.46	2990.0
34 ENTERTAINMENT	21.61	14.23	5.21	62.6	62.6	2.54	11.25	2.54	0.83	14.61	4261.9
35 LISTENING TO SOUNDS	4.07	6.26	1.78	72.5	72.5	1.12	2.12	1.12	0.28	3.52	1138.9
36 PERFORMING	1.36	0.53	3.04	23.2	23.2	0.09	0.71	0.09	0.43	1.28	396.2
37 HOBBIES AND CRAFTS	7.45	10.56	26.62	44.0	44.0	1.88	3.88	1.88	4.24	10.00	3376.0
38 PERSONAL LETTERS	4.07	6.33	15.21	12.6	12.6	1.13	2.12	1.13	2.42	5.67	1928.5
TOTAL	1440.00	1440.00	1440.00	11961.3	11961.3	256.74	749.48	256.74	229.34	1235.56	387611.9

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE \$12,000-19,999 HOUSEHOLD INCOME CLASS

	TOTAL EXPENSE BILLION \$	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1 JOBS	263.3188	2	0.0000	--	--	--
2 TRAVEL TO JOB	40.1922	11	1.9641	15	1.7283	19
3 FOOD PREPARATION	65.7891	3	1.6952	16	1.6347	20
4 HOUSE CLEANING	24.7764	15	0.1439	30	18.6356	5
5 GARDENING	2.6632	31	2.5163	10	1.1849	26
6 PET CARE	2.8515	32	4.3987	6	0.6820	29
7 CLOTHING AND LINENS	40.7956	10	3.0153	8	0.9238	27
8 HOUSE	59.4268	6	13.1800	2	0.2601	33
9 MEDICAL CARE GIVEN	2.5506	33	10.1865	3	0.3093	32
10 CHILD CARE	22.6501	16	0.5676	26	4.9703	9
11 FINANCIAL MANAGEMENT	45.8027	9	3.8117	7	0.8095	28
12 TRAVEL/PRO MEDICAL	1.3223	36	5.5067	5	0.5888	30
13 TRAVEL/EDUCATION	1.0389	37	2.2197	13	1.4958	21
14 TRAVEL/ORG & RELIGION	4.9919	28	2.5268	9	1.2632	24
15 TRAVEL/SOCAL LIFE	14.7525	19	2.4996	11	1.2723	23
16 TRAVEL/LEISURE	2.5331	34	2.4979	12	1.2547	25
17 SHOPPING/NON-TRADABLE	10.6062	23	1.5940	18	1.9634	18
TOTAL--TRADABLE	626.4700		1.1419		2.7864	
18 PERSONAL CARE SHOME	52.3273	7	0.1226	32	25.4435	3
19 PERSONAL CARE SERVICES	3.4129	30	6.1097	4	0.4835	31
20 MED CARE RECEIVE SHOME	0.2394	39	0.0000	--	--	--
21 PRO MEDICAL CARE	12.0002	21	36.0600	1	0.0867	34
22 EATING AT HOME	51.5343	8	0.0000	--	--	--
23 EATING OUT	34.1067	13	1.6325	17	2.0910	17
24 SLEEP AND REST	395.9065	1	0.0000	--	--	--
25 VACATION	26.0497	14	0.9953	23	3.2024	12
26 EDUCATION	7.6590	26	1.3772	19	2.2963	16
27 RELIGION	9.1327	24	2.2062	14	1.4079	22
28 OTHER ORGANIZATIONS	8.1291	25	0.5174	27	6.1956	8
29 TELEVISION	67.8599	4	0.0764	34	43.3185	1
30 READING	34.4454	12	0.1161	33	20.5092	2
31 SOCIAL LIFE	66.3586	5	0.6694	25	4.5008	10
32 CONVERSATION	19.3594	17	0.8793	24	3.5044	11
33 OUTDOORS	14.3344	20	1.2988	20	2.7037	14
34 ENTERTAINMENT	15.6276	18	0.2048	28	12.0386	6
35 LISTENING TO SOUNDS	4.9225	29	1.2346	21	2.5008	15
36 PERFORMING	1.7335	35	1.1348	22	2.8561	13
37 HOBBIES AND CRAFTS	10.6557	22	0.2530	29	11.7083	7
38 PERSONAL LETTERS	5.9119	27	0.1264	31	23.2576	4
TOTAL	1467.6143		0.5997		5.3245	

ASSUMPTIONS ABOUT THE THE \$12,000-19,999 HOUSEHOLD INCOME CLASS

	WAGE RATE (\$/HOUR AFTER TAX)	POPULATION (MILLIONS)
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EMPLOYED MEN	4.01	21.34
EMPLOYED WOMEN	2.20	13.32
HOUSEHOLDS	2.73	9.59

TOTAL NUMBER OF HOUSEHOLDS 19.40 MILLION

VALUE OF TIME VS. MARKET EXPENDITURES FOR THE OVER \$20,000 HOUSEHOLD INCOME CLASS

ACTIVITY	MINUTES/DAY				1973 \$/HOUSE-				BILLION 1973 \$			
	EMPLOYED MEN	EMPLOYED WOMEN	HOUSEWIVES	HOLD MARKET EXPENDITURES	EMPLOYED MEN	EMPLOYED WOMEN	HOUSEWIVES	HOUSEWIVES	HOUSEWIVES	HOUSEWIVES	HOUSEWIVES	PERSONAL HOURS (MIL- LIONS)
1 JOB	374.25	292.64	4.25	0.0	185.69	49.87	0.34	0.34	235.90	0.00	0.00	48696.6
2 TRAVEL TO JOB	52.92	32.23	1.42	1036.3	26.26	5.49	0.11	0.11	31.86	10.49	10.49	6412.6
3 FOOD PREPARATION	23.55	79.79	146.63	2097.6	11.69	13.60	11.80	11.80	37.08	21.23	21.23	10866.5
4 HOUSE CLEANING	7.42	49.76	74.47	122.5	3.68	8.48	5.99	5.99	18.15	1.24	1.24	5625.8
5 GARDENING	1.45	4.96	4.67	122.6	0.72	0.85	0.38	0.38	1.94	1.24	1.24	535.5
6 PET CARE	1.07	3.44	3.34	108.0	0.53	0.59	0.27	0.27	1.39	1.09	1.09	382.4
7 CLOTHING AND LINENS	6.62	30.51	44.35	1726.7	3.29	5.20	3.57	3.57	12.05	17.47	17.47	3590.1
8 HOUSE	19.38	7.68	18.69	3482.6	9.62	1.31	1.50	1.50	12.43	35.24	35.24	2678.2
9 MEDICAL CARE GIVEN	0.55	0.64	1.23	136.0	0.27	0.11	0.10	0.10	0.48	1.38	1.38	120.2
10 CHLD CARE	6.56	16.74	56.45	253.0	3.27	3.19	4.54	4.54	11.00	2.56	2.56	3314.7
11 FINANCIAL MANAGEMENT	22.60	35.48	62.37	2129.6	11.21	6.05	5.02	5.02	22.28	21.55	21.55	5803.1
12 TRAVEL/PRO MEDICAL	0.46	0.57	0.90	58.5	0.23	0.10	0.07	0.07	0.40	0.59	0.59	98.8
13 TRAVEL/EDUCATION	0.69	0.32	0.92	29.3	0.34	0.05	0.07	0.07	0.47	0.30	0.30	105.2
14 TRAVEL/ORG & RELIGION	2.78	1.93	4.62	155.2	1.39	0.33	0.37	0.37	2.09	1.57	1.57	487.9
15 TRAVEL/SOCAL LIFE	8.33	6.44	12.00	456.7	4.13	1.10	0.97	0.97	6.19	4.62	4.62	1442.4
16 TRAVEL/LEISURE	1.39	1.29	1.85	79.0	0.69	0.22	0.15	0.15	1.06	0.80	0.80	247.4
17 SHOPPING/NON-TRADABLE	6.45	8.09	13.17	251.8	3.20	1.30	1.06	1.06	5.64	2.55	2.55	1404.0
TOTAL--TRADABLE	536.49	574.43	451.33	12245.4	266.19	97.90	36.31	36.31	400.40	123.92	123.92	91814.9
18 PERSONAL CARE SHOME	51.31	73.70	76.78	131.1	25.46	12.56	6.18	6.18	44.20	1.33	1.33	10827.4
19 PERSONAL CARE SERVICES	0.90	1.99	2.23	185.1	0.45	0.34	0.19	0.19	0.97	1.80	1.80	254.0
20 MED CARE RECEIVE SHOME	0.23	0.25	0.56	0.0	0.11	0.04	0.04	0.04	0.20	0.00	0.00	50.1
21 PRO MEDICAL CARE	0.90	1.00	2.23	772.2	0.45	0.17	0.19	0.19	0.80	7.81	7.81	200.6
22 EATING AT HOME	51.86	53.80	69.49	0.0	25.73	9.17	5.59	5.59	40.49	0.00	0.00	9569.3
23 EATING OUT	29.12	26.90	5.87	863.7	14.45	4.58	0.47	0.47	19.50	8.94	8.94	4182.4
24 SLEEP AND REST	481.81	488.03	471.25	0.0	239.05	79.76	37.92	37.92	356.73	0.00	0.00	81857.9
25 VACATION	21.66	21.65	21.67	717.6	10.75	3.69	1.74	1.74	16.18	7.26	7.26	3727.6
26 EDUCATION	13.05	4.89	13.11	388.2	6.47	0.83	1.05	1.05	8.36	3.93	3.93	1802.8
27 RELIGION	6.23	13.35	9.95	362.4	3.09	2.29	0.80	0.80	6.17	3.67	3.67	1573.7
28 OTHER ORGANIZATIONS	0.22	0.00	9.00	208.6	0.11	0.00	0.72	0.72	0.83	2.11	2.11	293.2
29 TELEVISION	74.07	48.32	65.73	90.4	36.75	8.23	5.29	5.29	50.28	0.91	0.91	11093.4
30 READING	57.26	38.74	57.68	96.1	28.41	6.60	4.64	4.64	39.65	0.97	0.97	8859.9
31 SOCIAL LIFE	67.61	39.58	112.29	1170.5	33.54	6.74	9.03	9.03	49.32	11.85	11.85	11472.3
32 CONVERSATION	13.92	26.19	28.32	253.3	6.91	4.46	2.28	2.28	13.65	2.66	2.66	3503.0
33 OUTDOORS	11.06	5.07	1.14	399.3	5.49	0.86	0.09	0.09	6.45	4.04	4.04	1275.7
34 ENTERTAINMENT	2.57	13.49	14.33	111.4	1.28	2.30	1.15	1.15	4.73	1.13	1.13	1395.4
35 LISTENING TO SOUNDS	10.71	7.50	1.61	105.7	5.32	1.28	0.13	0.13	6.72	1.07	1.07	1391.4
36 PERFORMING	0.95	0.64	1.73	58.0	0.47	0.11	0.14	0.14	0.72	0.59	0.59	170.1
37 HOBBIES AND CRAFTS	5.22	12.77	15.10	76.9	2.59	2.19	1.22	1.22	5.98	0.78	0.78	1610.8
38 PERSONAL LETTERS	2.85	7.66	8.63	16.8	1.41	1.31	0.69	0.69	3.41	0.17	0.17	920.5
TOTAL	1440.00	1440.00	1440.00	18283.4	714.47	245.40	115.86	115.86	1075.73	105.03	105.03	247854.5

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE OVER \$20,000 HOUSEHOLD INCOME CLASS

	TOTAL EXPENSE BILLION \$	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1 JOB	235.8998	2	0.0000	--	----	--
2 TRAVEL TO JOB	42.3510	9	1.6355	23	3.0382	12
3 FOOD PREPARATION	58.3070	4	1.9535	20	1.7468	17
4 HOUSE CLEANING	19.3934	15	0.2204	30	14.6395	5
5 GARDENING	3.1791	29	2.3037	17	1.5625	21
6 PET CARE	2.4793	32	2.6599	14	1.2679	25
7 CLOTHING AND LINENS	29.5275	12	4.8674	7	0.6897	28
8 HOUSE	47.6747	6	13.1595	2	0.3527	32
9 MEDICAL CARE GIVEN	1.8567	33	11.4465	3	0.3490	33
10 CHILD CARE	13.5624	17	0.7725	26	4.2962	9
11 FINANCIAL MANAGEMENT	43.8282	8	3.7138	8	1.0337	27
12 TRAVEL/PRO MEDICAL	0.9916	36	5.9976	6	0.6737	29
13 TRAVEL/EDUCATION	0.7696	37	2.7897	15	1.5994	19
14 TRAVEL/ORG & RELIGION	3.6480	27	3.2184	11	1.3232	23
15 TRAVEL/SOCAL LIFE	10.8161	19	3.2043	12	1.3402	22
16 TRAVEL/LEISURE	1.9563	34	3.2329	10	1.3210	24
17 SHOPPING/NON-TRADABLE	8.1957	23	1.8148	22	2.2126	14
TOTAL--TRADABLE	524.3245		1.3497		3.2310	
18 PERSONAL CARE SHOME	45.5239	7	0.1225	32	33.3256	3
19 PERSONAL CARE SERVICES	2.8483	31	7.3909	4	0.5126	30
20 MED CARE RECEIVE SHOME	0.1939	35	0.0000	--	----	--
21 PRO MEDICAL CARE	8.6097	22	38.9826	1	0.1018	34
22 EATING AT HOME	40.4913	11	0.0000	--	----	--
23 EATING OUT	28.4459	13	2.1363	19	2.1808	15
24 SLEEP AND REST	356.7312	1	0.0000	--	----	--
25 VACATION	23.4402	14	1.9482	21	2.2278	13
26 EDUCATION	12.2690	18	2.1793	18	2.1279	16
27 RELIGION	9.8360	21	2.3307	16	1.6818	18
28 OTHER ORGANIZATIONS	2.9431	30	7.1980	5	0.3941	31
29 TELEVISION	51.1905	5	0.0825	34	54.9496	1
30 READING	40.6239	10	0.1097	33	40.7793	2
31 SOCIAL LIFE	61.1685	3	0.0325	24	4.1640	11
32 CONVERSATION	16.5143	16	0.7607	28	5.1222	8
33 OUTDOORS	10.4861	20	3.1674	13	1.5952	20
34 ENTERTAINMENT	5.8550	26	0.8079	25	4.1939	10
35 LISTENING TO SOUNDS	7.7920	24	0.7685	27	6.2368	7
36 PERFORMING	1.3051	35	3.4465	9	1.2247	26
37 HOBBIES AND CRAFTS	6.7593	25	0.4832	29	7.6854	6
38 PERSONAL LETTERS	3.5822	28	0.1826	31	20.1299	4
TOTAL	1260.7563		0.7465		5.8138	

ASSUMPTIONS ABOUT THE THE OVER \$20,000 HOUSEHOLD INCOME CLASS

	WAGE RATE (\$/HOUR AFTER TAX)	POPULATION (MILLIONS)
EMPLOYED MEN	5.69	14.33
EMPLOYED WOMEN	3.13	8.95
HOUSEHIVES	2.64	5.01
TOTAL NUMBER OF HOUSEHOLDS		10.12 MILLION

VALUE OF TIME VS. MARKET EXPENDITURES FOR ALL HOUSEHOLDS

ACTIVITY	MINUTES/DAY				1973 \$/HOUSE- HOLD MARKET EXPEND- ITURES	BILLION 1973 \$				PERSON HOURS (MIL- LIONS)		
	EMPLOYED MEN	EMPLOYED WOMEN	HOUSE- WIVES	HOUSE- WIVES		EMPLOYED MEN VALUE OF TIME	EMPLOYED WOMEN VALUE OF TIME	HOUSE- WIVES VALUE OF TIME	TOTAL VALUE OF TIME			
1 JOB	391.60	298.28	3.98	0.0	0.0	525.90	143.09	4.07	673.05	0.00		
2 TRAVEL TO JOB	40.69	28.31	0.43	565.5	565.5	59.13	14.29	0.45	73.87	18541.5		
3 FOOD PREPARATION	24.51	86.84	155.56	1360.9	1360.9	34.08	39.45	95.22	168.75	58214.8		
4 HOUSE CLEANING	7.48	42.41	77.17	56.5	56.5	10.46	20.92	46.34	77.73	27268.5		
5 GARDENING	1.67	1.88	3.60	54.9	54.9	2.03	1.40	1.88	5.31	1659.9		
6 PET CARE	1.23	1.39	2.56	65.9	65.9	1.52	1.00	1.34	3.86	1208.2		
7 CLOTHING AND LINENS	7.57	33.92	66.17	862.8	862.8	9.56	13.67	37.99	61.61	23264.4		
8 HOUSE	15.45	6.84	11.82	2032.1	2032.1	24.04	3.28	6.95	34.28	8757.5		
9 MEDICAL CARE GIVEN	0.59	0.62	0.95	83.0	83.0	0.81	0.30	0.56	1.67	514.0		
10 CHILD CARE	6.54	21.92	74.05	144.4	144.4	10.68	9.59	46.90	67.16	22828.0		
11 FINANCIAL MANAGEMENT	20.27	31.96	40.36	914.6	914.6	28.59	14.21	22.80	65.60	21351.9		
12 TRAVEL/PRO MEDICAL	0.49	0.50	0.57	31.9	31.9	0.70	0.25	0.34	1.29	375.3		
13 TRAVEL/EDUCATION	0.75	0.40	0.75	16.0	16.0	1.02	0.18	0.43	1.63	475.9		
14 TRAVEL/ORG & RELIGION	3.02	2.38	3.73	84.7	84.7	4.08	1.09	2.17	7.33	2224.2		
15 TRAVEL/SOCIAL LIFE	9.05	7.94	9.70	249.2	249.2	12.23	3.63	5.63	21.49	6509.7		
16 TRAVEL/LEISURE	1.51	1.59	1.49	43.1	43.1	2.04	0.73	0.87	3.63	1110.6		
17 SHOPPING/NON-TRADABLE	6.96	8.02	9.23	137.4	137.4	9.59	3.94	5.47	19.00	5761.4		
TOTAL--TRADABLE	541.39	575.21	462.12	6702.9	6702.9	736.85	271.00	279.41	1207.26	39363.4		
18 PERSONAL CARE @HOME	55.31	71.77	67.42	79.1	79.1	73.33	32.59	36.83	144.75	46090.3		
19 PERSONAL CARE SERVICES	0.97	1.94	1.95	92.9	92.9	1.29	0.88	1.13	3.29	1103.2		
20 MED CARE RECEIVE @HOME	0.24	0.24	0.49	0.0	0.0	0.32	0.11	0.23	0.71	229.2		
21 PRO MEDICAL CARE	0.97	0.97	1.95	473.3	473.3	1.29	0.44	1.13	2.85	33.71		
22 EATING AT HOME	56.34	46.66	70.05	0.0	0.0	77.25	23.36	39.53	140.15	42025.7		
23 EATING OUT	34.63	23.33	5.92	441.1	441.1	43.37	11.68	3.34	58.39	15870.6		
24 SLEEP AND REST	461.86	470.79	481.47	0.0	0.0	636.30	218.92	300.47	1155.69	342062.4		
25 VACATION	23.77	23.73	23.77	262.7	262.7	32.93	11.26	14.46	59.67	17250.3		
26 EDUCATION	8.74	5.06	5.11	105.5	105.5	12.43	2.05	2.82	17.30	4854.3		
27 RELIGION	7.04	8.90	14.39	156.3	156.3	9.04	3.74	8.14	19.92	7065.5		
28 OTHER ORGANIZATIONS	5.33	3.05	10.43	59.0	59.0	5.75	0.80	5.18	11.74	4521.1		
29 TELEVISION	96.27	61.92	95.13	62.3	62.3	117.84	25.76	64.18	207.78	63031.3		
30 READING	37.79	26.09	36.52	47.7	47.7	61.41	14.83	20.01	96.25	24917.8		
31 SOCIAL LIFE	61.01	65.01	89.69	541.0	541.0	81.62	27.76	57.70	167.09	51332.4		
32 CONVERSATION	12.91	17.82	30.09	178.0	178.0	18.34	9.08	18.39	45.81	14043.6		
33 OUTDOORS	12.45	5.27	4.56	143.8	143.8	18.35	3.29	2.53	24.17	5956.1		
34 ENTERTAINMENT	11.07	10.84	6.29	49.2	49.2	16.42	5.72	3.56	25.71	6855.1		
35 LISTENING TO SOUNDS	5.85	5.25	3.12	58.7	58.7	9.36	2.94	1.99	14.29	3554.0		
36 PERFORMING	0.95	0.49	2.00	10.6	10.6	1.43	0.26	1.07	2.76	827.0		
37 HOBBIES AND CRAFTS	5.24	9.80	17.52	32.9	32.9	7.87	5.17	9.36	22.40	7346.2		
38 PERSONAL LETTERS	2.66	5.66	10.01	9.5	9.5	4.29	3.10	5.35	12.74	4208.9		
TOTAL	1440.00	1440.00	1440.00	9513.6	9513.6	1965.09	674.78	878.85	3519.73	677.46		

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR ALL HOUSEHOLDS

	TOTAL EXPENSE BILLION \$	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1 JOB	673.0468	2	0.0000	--	----	--
2 TRAVEL TO JOB	114.1355	11	2.1717	14	1.8345	19
3 FOOD PREPARATION	265.6624	3	1.6647	18	1.7413	21
4 HOUSE CLEANING	81.7571	14	0.1476	31	19.3143	4
5 GARDENING	9.2173	31	2.3410	13	1.3578	23
6 PET CARE	8.5321	32	3.8651	6	0.8219	29
7 CLOTHING AND LINENS	123.0567	10	2.6410	11	1.0028	29
8 HOUSE	178.9853	6	16.5050	2	0.2359	33
9 MEDICAL CARE GIVEN	7.5795	33	11.4954	3	0.2828	32
10 CHILD CARE	77.4410	15	0.4504	28	6.5317	8
11 FINANCIAL MANAGEMENT	130.7249	9	3.0498	7	1.0072	27
12 TRAVEL/PRO MEDICAL	3.5617	36	6.0607	4	0.5657	30
13 TRAVEL/EDUCATION	2.7715	37	2.3850	12	1.4367	22
14 TRAVEL/ORG & RELIGION	13.3613	29	2.7105	10	1.2163	24
15 TRAVEL/SOCIAL LIFE	39.2392	18	2.7259	9	1.2113	25
16 TRAVEL/LEISURE	6.7021	34	2.7652	8	1.1824	26
17 SHOPPING/HCN-TRADABLE	28.7811	23	1.6950	17	1.9420	17
TOTAL--TRADABLE	1764.5752		1.2441		2.6969	
18 PERSONAL CARE SHINE	150.3827	7	0.1222	33	25.7043	3
19 PERSONAL CARE SERVICES	9.9050	30	5.9665	5	0.4980	31
20 MED CARE RECEIVE SHINE	0.7131	30	0.0000	--	----	--
21 PRO MEDICAL CARE	36.5594	19	36.7666	1	0.0046	34
22 EATING AT HOME	140.1457	8	0.0000	--	----	--
23 EATING OUT	89.3035	13	1.9792	15	1.8520	10
24 SLEEP AND REST	1155.6926	1	0.0000	--	----	--
25 VACATION	77.3771	16	1.0921	23	3.1357	12
26 EDUCATION	24.8189	24	1.5481	21	2.3025	15
27 RELIGION	31.0529	21	1.5754	20	1.7890	20
28 OTHER ORGANIZATIONS	15.0654	27	0.9135	24	2.0415	13
29 TELEVISION	212.2163	4	0.0704	34	46.0288	1
30 READING	99.6497	12	0.1354	32	28.3208	2
31 SOCIAL LIFE	205.6097	5	0.7505	26	4.3373	9
32 CONVERSATION	58.4837	17	9.9028	25	3.6128	10
33 OUTDOORS	34.4161	20	1.7197	16	2.3500	14
34 ENTERTAINMENT	29.2116	22	0.5015	27	7.3383	7
35 LISTENING TO SOUNDS	18.4763	26	1.1764	22	3.4181	11
36 PERFORMING	4.0799	35	1.5975	19	2.0692	16
37 HOBBIES AND CRAFTS	24.7392	25	0.3163	29	9.5678	6
38 PERSONAL LETTERS	13.4218	28	0.1614	30	18.7553	5
TOTAL	4197.1875		0.6465		5.1954	

ASSUMPTIONS ABOUT THE ALL HOUSEHOLDS

	WAGE RATE (\$/HOUR AFTER TAX)	POPULATION (MILLIONS)
EMPLOYED MEN	3.80	51.96
EMPLOYED WOMEN	2.09	32.44
HOUSEWIVES	2.85	35.22
TOTAL NUMBER OF HOUSEHOLDS		71.31 MILLION

GOVERNMENT PATENT POLICY
An Analysis of the Effects of Three Alternative Patent Policies
on Technology Transfer and the Commercialization
of Government Inventions

by

Mark Matousek

October 1979

National Aeronautics and Space Administration
Contract NASW 3204

Report No. 27

PROGRAM IN INFORMATION POLICY

Engineering-Economic Systems Department
Stanford University **Stanford, California 94305**

ABSTRACT

This paper addresses the effects of present and proposed Government patent policies on the process of technology transfer and the commercialization of inventions resulting from Government sponsored research.

The function of the patent system in Government research and the value of patents resulting from Government sponsored research are examined.

Three alternative patent policies--title in the contractor, title in the Government, and the waiver policy--are examined in terms of their effects on the commercialization of inventions, industrial competition, disclosure of inventions, participation of research contractors and administrative costs.

Efforts to reform the present Government patent policy are also described.

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Introduction

The problems with the present patent policy for federally funded R&D--(1) lack of uniformity in individual agency policies, and (2) a very low rate of commercialization--are fairly well agreed upon, but which approach offers the best solution is still being debated with the same arguments as in 1949. But the following factors point to an increasing momentum towards some means of resolution:

- the growing concern and the resulting administrative domestic policy review over the declining rate of U.S. technological innovation;
- the recent presidential proposal for a uniform Government patent policy allowing contractors to retain exclusive licenses to resulting inventions; and
- the introduction of four bills during the 96th Congress dealing exclusively with the Government's patent policy.

The present movement in Congress to reform the Government's Patent Policy has been a long and slow moving process. Present efforts to establish a uniform policy date back to the rapid build up of government sponsored research during the second world war. Congressional patent policy guidance since that time has oscillated between a policy where the Government obtains title to all inventions arising from Government research contracts (the "title policy") and a policy where the contractor retains the title to such inventions while the Government obtains a paid-up, irrevocable license to use the invention (the "license policy").

The Carter administration recently announced its proposed Government patent policy which would allow small businesses and non-profit corporations to retain title to resulting inventions while allowing large corporations the right to obtain only an exclusive license to resulting inventions and only within a designated "field of use." This proposal is currently only a recommendation and has not been issued as a binding executive order.

There are two distinct views of the function of the patent system--as a reward for an inventor's creativity or as an incentive for the creation, development and commercialization of inventions. This paper addresses only the latter since it is this function that is important in the process of technology utilization.

The patent system was adopted in the United States to "promote the progress of science and the useful arts." [1] It accomplishes this function by providing the inventor with an exclusive right (in essence a property right) to the use of his invention. The patent system attempts to thereby encourage inventiveness, development and commercialization of inventions and the reporting of new inventions and hence the widespread public availability of new technological ideas.

There are two interpretations of the incentive function of the patent system; first, that the patent increases the incentives for people to invent socially useful (i.e., profitable) patentable technologies and that it also increases the incentives to develop, test and market (i.e., commercialize)

these inventions.

Outside of Government sponsored research, the patent system's influence on calculated profit may direct the inventor's activity into channels of general usefulness. [2] But under Government research contracts, where the area and amount of research are fairly well-defined prior to the research, the major determinant of the number of useful inventions is the quality of the researchers sponsored and the level of Government funding. The ability of a contractor or specific inventor to obtain the patent rights to the resulting inventions is unlikely to greatly alter the type or quality of the research.

The more important incentive provided by patents in Government sponsored research is the incentive for the patent recipient to promote or perform the invention's commercialization and thus reap the benefits offered by the patent rights. This function has also been called the prospect function [3], since it is closely analogous to the American mineral claim system or homesteading system on public lands. The function of each is to promote the utilization of an otherwise public resource at an efficient rate which maximizes the amount of the social benefits produced.

This argument rests upon the assumptions that the \$30 billion of Government sponsored research produces patentable inventions that have social value and that the ability of an inventor to capture a larger share of the invention's social benefits as profits increases the probability of the invention's

commercialization. Since social benefits are the sum of producer and consumer surplus, the profits made by the inventor still are a benefit to society. Viewed in this way, if a license policy increases the probability that a socially useful invention will be made commercially available as compared to a title policy, then it results in greater social benefits and should therefore be preferred. Therefore, the claim that a license policy is a "giveaway" of public property seems unreasonable although part of the social benefits will temporarily be in the form of private profits.

The two primary arguments against the incentive function are that patents are only a minor inducement to private firms to develop and commercialize inventions in comparison to factors such as the expected commercial value of the invention, and the cost of developing the invention; and secondly that any social benefits resulting from the patent system are outweighed by the costs resulting from the dislocation of resources caused by the patent system.

The dislocation costs refer to the outputs lost when resources are diverted to the inventing of patentable ideas from their previous use.

"insofar as inducement (to inventive activity) is furnished only by the expectation of a patent monopoly, a diversion of resources takes place and other production is foregone. What grounds are there for concluding that the output induced by this type of monopoly has any greater claim to be regarded as 'generally useful' than that which would have been induced in its absence by the open market?" [4]

The Value of Patents Resulting from Government Sponsored Research

There are a number of misconceptions regarding the number and value of the patents resulting from Government funded research which have traditionally overestimated both the number and the value of these patents. As an example, there were .41 inventions per million dollars of NASA research, funded in 1978 (NASA R&D expenditures in 1978 = \$3.011 billion, 1978 invention disclosures = 1239). There were .074 inventions on which patent applications were filed per million dollars of research and .044 inventions on which patents were granted (assuming the Patent Office's historical .6 ratio of patents granted to applications filed) per million dollars of research.

From this small number of patented inventions different studies have shown that from 1-20% of these will be commercially used and even a smaller number will yield any income.

The incomes yielded from those commercialized have usually been quite moderate. Therefore the expected value of the patentable inventions resulting from NASA sponsored research has been quite low. Similar results can also be found in private firms, Research Corporation, and others although the rates of both disclosure per dollar of research and commercialization of inventions disclosed have been somewhat higher.

Therefore, the claims that Government contractors that obtain patent rights may make millions of dollars is not supported in fact. Nor is the claim that the Government ownership of rights to inventions results in multimillion

dollar losses. But this is not to say that patent rights do not provide a relatively important incentive to private firms to commercialize these inventions. This relatively high perceived value of this incentive can be seen in the very active support many private firms have given to policies which allow the contractor to obtain exclusive rights to the invention.

Analysis of Alternative Patent Policies

This section of the paper examines three policies--the title policy, the license policy, and NASA's present waiver policy--upon the basis of the costs and benefits resulting from each policy. The costs and benefits are broken down into the policies' effects in five sectors:

- o commercialization or utilization of inventions,
- o competition,
- o participation of contractors in Government research,
- o disclosure of inventions, and
- o administrative costs of the program.

This report does not place quantitative values on these costs and benefits because of the unavailability of sufficient data to give reliability to such results.

Commercialization of Inventions

The effect of Government patent policy on the rate of utilization of Government sponsored inventions has traditionally been the most important issue in the debate between advocates of the title and license policies. Commercialization is .

important because it is the major means by which an invention reaches the public and its advantages (cost reduction, increased product quality, ...) are transformed into social benefits. Most supporters of the license policy have claimed that the increased likelihood of commercialization of inventions is the greatest advantage in allowing contractors to retain exclusive rights to their inventions. This argument is based on the assumptions that most high technology companies are more capable of promoting the dissemination and use of inventions than the Government and that exclusive rights provide a necessary incentive to bring forth the risk capital necessary for the development, marketing, and commercialization of new inventions. Title policy proponents have responded that not only are patents a minor determinant in corporate decisions to commercialize inventions, but the potential inability of interested future developers to gain access to the technology results in an actual decrease in the likelihood of commercialization.

License Policy Arguments:

There are two major arguments behind the position that the ability of contractors to retain title to inventions will increase the rate of commercialization of Government sponsored inventions;

- o a patent provides a contractor with the exclusive right to license or use an invention, resulting in a reduction of the risks accompanying its development and commercialization and thereby increasing

the incentives for the investment of the necessary risk capital,

- o contractors who have retained title to inventions have been more successful at commercializing those inventions than the sponsoring agency, in part because of their closer tie to the marketplace and prospective developers (oftentimes the contractors themselves) and the possession of a product "champion" (the inventor himself).

The first of these two arguments is based upon the "prospect" theory of a patent (discussed in the previous section). This view of the patent system envisions the patent, not as a reward for past inventiveness, but as a necessary incentive to develop, test, and use or market an invention. Traditionally, the cost required for development and commercialization of an invention have been an order of magnitude (or more) larger than the basic research costs. For NASA inventions, the private or public utilization of space technology usually requires large costs in adaptive engineering, development and marketing. By reducing the risk of other companies appropriating the results of this process of commercialization, patents provide a greater incentive for contractors to invest capital and, as the Harbridge House Study on Government Patent Policy pointed out, it is the lack of full technical development of Government inventions that has been the most frequent and important barrier to industrial use [5] . A patent does not disallow others from

using a patented technology, it only demands that they negotiate a reasonable payment for its use with the patent owner.

One result of this incentive is an increase in the amount of private resources being expended on technological innovation, an increase which most economists have regarded as being important both in reversing the declining levels of U.S. productivity and in modernizing technological industries that have fallen behind foreign competitors.

In support of the second argument, there is statistical evidence that contractors actually have been substantially more successful than the Government in promoting the commercialization of Government sponsored inventions, either through inter-corporate licensing or in-house development. Of the over 1200 NASA inventions to which contractors have obtained title since 1959, approximately 16% have been commercialized (Appendices B and C). In comparison, of the over 3500 inventions to which the Government has acquired patents since 1959, only 1% have been commercialized (Appendices D and E).

These figures are subject to question because of the difficulty in obtaining data many years after initial invention, the variation in definitions of "commercialization" and the statistical bias caused by contractors requesting the most commercially attractive inventions under a waiver policy. This variation is indicated in Appendix F showing the results of five different studies of the commercialization of NASA inventions. The most reliable data is probably that

compiled by NASA's patent and licensing office, since their data gathering techniques are the most extensive and their definitions have been subject to only minor variations over time (Appendices B, C, D, and E).

These higher rates of commercialization by contractors are caused in part by contractors requesting waivers on the commercially valuable inventions, but there are a number of other factors also involved. Contractors are usually chosen because of their being the most qualified in a certain field of research and, therefore, they are often in the best position to promote the commercialization of inventions in that field. These companies or universities as a result usually have much closer ties to the marketplace than do the sponsoring agencies. These contractors are also guided by the profits that inventions can offer to channel their investments into areas of public usefulness. They also have greater freedom in the types of license agreements that they can subsequently negotiate with other users of the invention.

Contractors also already have a "product champion" since it is usually the inventor that has the greatest interest in seeing an invention actually developed and utilized. It is widely believed that the transfer of a technology from one organization to another requires the transfer of people familiar with the technology. One obvious solution is to provide inventions to the organization possessing the technology to develop it themselves. Patent rights provide this type of incentive.

It is interesting to note that the patent attorneys at several agencies, including agencies which now pursue a waiver policy, have informally supported the use of a license policy in almost all Government research contracts (Appendix 6).

Title Policy Arguments:

There are three major arguments against contractors being allowed to retain title to inventions in order to encourage commercialization:

- o patents play a minor role in determining corporate decisions to commercialize inventions in comparison to factors such as favorable price conditions, the state of business confidence and costs of capital;
- o contractors retaining title to Government sponsored inventions are oftentimes interested in only making sure that their competitors don't use the inventions, thereby decreasing the likelihood of commercialization;
- o it is impossible to show that the gains from the movement of people and funds to the development of patentable inventions is not offset by losses in other areas of output--specifically the development of non-patentable inventions.

Waiver Policy Arguments:

The waiver policies adopted by NASA, DOE, NSF, AND HEW have offered several advantages. They are flexible and therefore allow contractors interested in commercializing an invention a chance (a 76% chance at NASA) to obtain exclusive rights to

an identified invention. In those cases where the contractor has not expressed an interest in the invention, or the waiver has been denied, the Government then has the opportunity to seek out other possible users on an exclusive or non-exclusive basis. Such a flexible system initially appears to offer the advantages of both the license and title policies, but there are a number of disadvantages as well.

It is obviously impossible for NASA's Invention or Contribution Board or DOE's patent office or any other Government entity responsible for waiver decisions to be able to know what the necessary factors are in an invention's commercialization.

Commercialization is dependent upon a number of complex unknowns such as future market demand, the quality of the invention, and the companies interest in the invention. Also present waiver guidelines support Government retention of title in cases where the "principal purpose of the contract is to create, develop or improve products, processes or methods which are intended for commercial use" or "which directly concern public health, public safety or public welfare," areas where it seems incentives to commercialize the inventions are the most important (see Appendix A).

Past records also show that many contractors perceive the waiver process as cumbersome and resulting in a waste of both time and money. Processing time for a waiver by NASA can vary from several weeks to a year depending upon the perceived urgency of the request. A waiver must also be

accompanied by a general outline of the contractor's proposed plan for the invention's commercialization. For large companies familiar with NASA's waiver process, the waiver requests do not pose a high cost. But for small companies or those unfamiliar with the waiver process, the costs of a waiver request may appear to be very substantial. Some NASA contractors have reported that they were unaware that waivers were even granted.

Another problem with the waiver system is that it introduces a factor of uncertainty in the commercialization process. An example of this uncertainty is provided by the changes that took place in HEW in 1978. Up until that time, HEW had followed a policy of granting most waiver requests to universities and small businesses (under Institutional Patent Agreements). Many contractors had participated in HEW contracts with this expectation, but in 1978 Secretary Califano called for a review of all future waivers and essentially froze all future waivers.

Effects on Industrial Competition

Opponents of a license policy have argued that the ability of contractors to retain patent rights has resulted in the formation of product monopolies, the increase of product costs to the consumer, and the lessening of market competition. Although patent rights do permit the private capture of returns created by the use of a patented invention, they by no means assure it. In fact, past studies have shown no significant examples of monopolization resulting from patents obtained on

Government sponsored inventions with the most extensive patent policy study concluding "that undue concentration would result from the license policy is a possibility so negligible that it may be disregarded" [6].

The main reason that contractor retained patents have not resulted in monopolization is, as previously mentioned, that there are few patented inventions of sufficient quality to allow the capture of a market. It is interesting to note that in thirty-four antitrust cases studied by the Harbridge House, where forced licensing of the defendant's patent portfolio had been one of the economic remedies for restraint of trade, only two companies in the survey have ever received applications for licenses although the patent portfolios were in some cases as large as 300 patents [7].

Monopolization has also not occurred because contractors have in general been very willing to license the use of their inventions to other users. In fact licensing has oftentimes provided the contractor with the most valuable means of optimizing the value of the patent, either in addition to or in place of in-house development.

A more reasonable concern than monopolization is that a few valuable inventions will be neither utilized nor promoted by the contractor. Since NASA currently publishes Tech Briefs and Technical Support Packages on contractor-owned patents arising from NASA sponsored research, this lack of use is presently minimized.

It should also be noted that the Government presently has a means of protecting against monopolization, "excessive profits" or non-use of an invention in the form of "march-in-rights." March-in-rights give the sponsoring agency the right either to require the contractor to license an invention to another company at a reasonable rate or to license the invention itself under certain limited conditions. Although march-in-rights have never been enforced, it seems that they could be used effectively in the few situations where they might be needed.

Of several agency patent counsels interviewed, a few stated that for march-in-rights to be effective the sponsoring agency must monitor the contractors' use of the invention through the submission of a contractor's invention utilization report. The submission of the utilization reports was said also to increase the likelihood of the contractor using the invention by encouraging a careful assessment of the invention's commercial value. Such a monitoring program could result in enforcement through the action of the contractor's competitors who could, in the case of valuable inventions, monitor their misuse and request the Government to enforce its march-in-rights.

It has also been suggested that when a contractor has not used the invention after a certain number of years that the patent rights should be transferred back to the sponsoring agency, so that it can promote the invention's utilization. However, such a proposal is plagued by the problem of defining a "reasonable

period of time" and what constitutes use of an invention.

Participation of Contractors

The willingness of a contractor to participate in Government sponsored research is highly dependent upon two factors: the contractor's perceived value of any resulting patents to which he may retain exclusive rights and the reasons a company enters into Government sponsored research.

For those companies that regard patents as an essential form of protection in developing a new product, the title policy may oftentimes deter the company from entering into a Government research contract. Past studies have shown that such companies are not in the majority and are concentrated in industries which are technologically based but innovate at a moderate rate (excluding rapidly innovative industries where trade secrets provide a more effective means of protection).

Many companies, especially large corporations, have traditionally regarded patents as being essentially defensive in nature (i.e., means of avoiding lawsuits for infringement by other companies who later patent a similar invention). For these companies, gaining exclusive rights to Government sponsored inventions has little value since the Government does not enforce infringement on the patents that it owns. The participation of those companies which see patents as having neither offensive nor defensive value are essentially unaffected by Government patent policy although several such companies have nonetheless vigorously supported a license policy.

Those companies which do value patent rights might be expected to lower their contract bids under a license policy by an amount proportional to the perceived value of the exclusive rights in any future inventions, although there has been no good evidence to substantiate such a belief. The value of potential patents rights to a contractor before performance of the contract are estimated to be worth less than one dollar (\$1) for an average one million research contract [8].

Many of the opponents of the title policy have claimed that that policy's major disadvantage is not the inflated cost of contractor's research bids but the lower quality of research that the Government obtains. This lower quality is due to a number of factors including the refusal of many of the most qualified contractors to perform Government research. Surveys of companies have shown that only a few companies actually refuse to participate because of an agency's patent policies. Lack of interest in the area of research, unwillingness to transfer the necessary personnel and facilities away from commercial research and a general unwillingness to work under Government supervision have been the more common reasons for qualified contractors not participating in Government research.

One area where contractor participation has been adversely affected is in contracts which require the availability to the public of any background patents; i.e., those privately owned patents which are deemed necessary for the use of any inventions

resulting from subsequent Government contracts. Companies have also claimed that participating in Government contracts has resulted in valuable proprietary information becoming publicly available because of the Freedom of Information Act and the requirement for background patents (Appendix 6).

There have also been claims that a large number of contractors segregate their industrial research teams from their Government research, resulting in a lower quality of Government research. If corporations' proprietary information has been jeopardized, such segregation seems to be a reasonable response.

NASA's ability to grant advance waivers should decrease the likelihood of losing the participation of qualified contractors. Advance waivers have been requested from NASA 906 times and granted 463 times between 1958 and 1978. Although considering how few advance waivers are requested, contractors apparently either perceive the waiver requests as time consuming and/or too expensive, or the value of obtaining patents is too low to justify such requests. Although the waiver request requires only the completion of a prepared form and the identification of the contractor's ability to commercialize or license any resulting inventions, many small companies are not aware of the process or view it as too expensive. This can be seen from the fact that the vast majority of NASA waiver requests come from large companies familiar with NASA's waiver policies.

Disclosure of Inventions

All Government research contracts require that contractors report any resulting inventions to the sponsoring agency. Disclosure is considered so important by some that a draft bill proposed by the Departments of Commerce and Justice in 1979 recommended criminal sanctions against any contractor not reporting new inventions. Aside from the complete infeasibility of such a proposal,* it indicates the fear by some Government officials that there are contractors who do not disclose inventions they see being commercially valuable and thus decrease the social benefits gained from the research.

A high rate of disclosure by itself is not advantageous, as can be seen from NASA's records. Some companies have traditionally reported large numbers of inventions that never proved of any commercial value, while others have only reported those inventions that they thought to be novel breakthroughs. Although the cost of screening an invention is not very high, since 1963 contractors have reported an average of nearly 1800 inventions annually, while only 5% of these have resulted in patent applications. In comparison, NASA employees have reported only an average of 335 inventions annually with 34% resulting in patent applications. It, therefore, is obvious that promoting disclosures is of and by itself of little value.

* Due to the inability to definitively define what constitutes an invention or the inability of, for example, a scientist in one field to recognize that his minor discovery may be a breakthrough in a completely different field.

It is not obvious that any patent policy is clearly advantageous in promoting the disclosure of valuable inventions. License policy advocates have claimed that the ability to retain exclusive rights would remove the disincentives for not reporting inventions. Yet in those contracts where NASA has granted advance waivers the number of inventions disclosed per dollar of research has declined substantially, although much of this is due to the contractor's diminished need to disclose inventions that are not of a patentable or otherwise valuable nature.

As the Deputy Assistant Attorney General for Antitrust matters recently remarked--

"We do not believe that disclosure has been a problem in private R&D contracting situations largely because of the high costs of concealment and the penalties in loss of reputation and future business caused by having concealment later discovered." [9]

Although there is little conclusive evidence to show that any one patent policy results in a more complete and effective disclosure of inventions, there is some evidence indicating that NASA's attempts to promote disclosures from contractors have resulted in an excess of disclosures of inventions that have little or no commercial value, wasting the time and money of both the contractor and the Government invention review board. This cost must, of course, be weighed against the possibility that a few valuable inventions might otherwise not be reported.

Administrative Costs

The administrative costs of each of the three Government patent policies is not very substantial and are unlikely to be a major factor in choosing between each policy. Nonetheless changes in policy could offer some cost reductions in comparison to NASA's waiver policy.

Presently the costs directly and indirectly attributable to NASA's waiver policy stem from the following activities;

- 1) compilation of the inventions disclosed by contractors and employees,
- 2) screening of the inventions by NASA and IITRI,
- 3) processing and filing of patent applications,
- 4) compilation of waiver requests,
- 5) compilation of licensing requests,
- 6) determination of waiver and license requests by the ICB,
- 7) review of the invention utilization reports, and
- 8) promotion and description of NASA inventions by the Technology Utilization office.

The license policy would decrease these administrative costs by decreasing both the number of inventions that must be screened for patent applications by the Technology Utilization office, eliminate the compilation and determination of waiver requests, decrease the number of license requests and determinations, and increase the number of invention utilization reports.

The title policy would increase the number of inventions to be screened, patented, licensed, and promoted and would eliminate the waiver compilation and determinations.

Several critics of NASA's present policy have claimed that NASA files patent applications on many more patents than are necessary. Since the Government only uses patents defensively, except when it is granting exclusive licenses, publication will give the same defense against infringement but without the cost of the patent application processing and filing fees.

Appendix A

NASA's Patent System

NASA's patent policy is based upon Section 305 of the National Aeronautics and Space Act of 1958 and the Presidential Memorandum on Government Patent Policy of 1971 (PRM). NASA's policy and procedures are detailed in NASA's revised implementing regulations (e.g., NASA Patent Waiver Regulations [10] ; NASA Domestic Patent Licensing Regulations [11] ; and NASA Foreign Patent Licensing Regulations [12]).

NASA's patent policy has evolved into a waiver policy which retains for the Government a broad, irrevocable royalty-free license but allows Government contractors to request the Government to waive its rights to the title of an invention to the contractor. Invention waivers may be requested either prior to performance of a contract for all resulting inventions (advance waivers) or after identification of an individual invention under a given contract. Recommendations on all waiver requests are made by the NASA Inventions and Contributions Board (ICB) to the NASA Administrator although almost no ICB recommendations have ever been reversed by the Administrator.

Guidelines to be considered by the ICB in considering waiver requests are outlined in the Space Act, Presidential Memorandum of 1971 and the implementing regulations. The stated objectives of NASA's patent policy are:

- o serving the public interest;
- o protecting public health, safety and welfare;
- o fostering inventiveness;
- o encouraging reporting of inventions;
- o providing for the widest possible dissemination of new technology;
- o promoting the investment of risk capital in new inventions;
- o promoting industrial competition;
- o promoting early utilization of inventions; and
- o avoiding undue market concentration.

There are similar guidelines of each Federal agency but widely varying interpretations of these objectives has resulted in each Federal department or agency developing a different patent policy.

Statistically, NASA's policy has been largely one of title in the Government with contractors acquiring title to only 4% of the contractor inventions disclosed. [13] This low percentage of contractor acquired rights is due primarily to the small number of contractor requests for waivers. Between 1959 and 1979, 76% of the requests for individuals' waivers had been granted with 51% of the requests for advance waivers being granted.

From these figures it would appear that either NASA has been patenting many inventions that their inventors do not perceive as having significant commercial potential and for

which the Government's rights could probably be just as effectively protected by publishing, or the process of requesting a waiver is or at least appears to contractors to be an overly expensive or time consuming obstacle to gaining title to an invention, or both.

NASA'S PATENT POLICY

Title In The Government

1) National Aeronautics and Space Act (1958):

"any invention conceived or actually reduced to practice in the performance of any work under any contract... becomes the exclusive property of the government unless the Administrator determines that the interests of the United States will be served by waiving all or any part of the Government's rights...." (section 305)

2) Presidential Memorandum (1971):

(a) Where

(1) a principal purpose of the contract is to create, develop or improve products, processes, or methods which are intended for commercial use (or which are otherwise intended to be made available for use) by the general public at home or abroad, or which will be required for such use by governmental regulations; or

(2) a principal purpose of the contract is for exploration into fields which directly concern the public health, public safety, or public welfare; or

(3) the contract is in a field of science or technology in which there has been little significant experience outside of work funded by the Government, or where the Government has been the principal developer of the field, and the acquisition of exclusive rights at the time of contracting might confer on the contractor a preferred or dominant position; or

(4) the services of the contractor are

(i) for the operation of a Government-owned research or production facility; or

(ii) for coordinating and directing the work of others, (Section 1)

Title In The Contractor

1) National Aeronautics and Space Act:

No such allowance mentioned.

2) Presidential Memorandum:

(b) In other situations, where the purpose of the contract is to build upon existing knowledge or technology, to develop information, products, processes, or methods for use by the Government, and the work called for by the contract is in a field of technology in which the contractor has acquired technical competence (demonstrated by factors such as know-how, experience, and patent position) directly related to an area in which the contractor has an established nongovernmental commercial position, the contractor shall normally acquire the principal or exclusive rights throughout the world in and to any resulting inventions.

(c) ...the agency may prescribe by regulation special situations where the public interest in the availability of the inventions would best be served by permitting the contractor to acquire at the time of contracting greater rights than a nonexclusive license. (Section 1)

3) Institutional Patent Agreements:

In accordance with the language regarding exceptional circumstances in 51-9 107-3(a) and/or the language regarding special situations in 51-9 107-3(c), agencies may enter into Institutional Patent Agreements (see 51-9 107-6(c)) with universities and nonprofit organizations having technology transfer programs meeting the criteria of 51-9 109-7(b). The agreements permit those institutions, subject to certain conditions, to retain the entire right, title, and interest in inventions made in the course of their contracts.

Waivers

1) National Aeronautics and Space Act:

(f) Under such regulations in conformity with this subsection as the Administrator shall prescribe, he may waive all or any part of the rights of the United States under this section with respect to any invention or class of inventions made or which may be made by any person or class of persons in the performance of any work required by any contract of the Administration of the Administrator determines that the interests of the United States will be served thereby. (Section 305)

2) Presidential Memorandum:

Advance Waivers;

In exceptional circumstances the contractor may acquire greater rights than a nonexclusive license at the time of contracting where the head of the department or agency certifies that such action will best serve the public interest. (Section 1(a))

...the agency may prescribe by regulation special situations where the public interest in the availability of the inventions would best be served by permitting the contractor to acquire at the time of contracting greater rights than a nonexclusive license. (Section 1(c))

Deferred Determination Waivers;

Greater rights may also be acquired by the contractor after the invention has been identified where the head of the department or agency determines that the acquisition of such greater rights is consistent with the intent of this Section 1(a) and is either a necessary incentive to call forth private risk capital and expense to bring the invention to the point of practical application or that the Government's contribution to the invention is small compared to that of the contractor. Where an identified invention made in the course of or under the contract is not a primary object of the contract, greater rights may also be acquired by the contractor under the criteria of Section 1(c). (Section 1(a))

Appendix B

NASA WAIVER STATISTICS 1959 THROUGH 1978*

Individual Waivers

1. Number of inventions reported by NASA contractors	31,357
2. Petitions for waiver requested	1,366
3. Waivers granted	1,035
4. Petitions denied	148
5. Petitions withdrawn	139
6. Petitions pending	44

Advance Waivers

1. Advance waivers requested	906
2. Advance waivers granted	463
3. Advance waivers denied	293
4. Requests withdrawn	111
5. Requests pending	39
6. Number of inventions reported under contracts having advance waivers and contractor intends to file	216

Inventions Waived

1. Total inventions waived	1,254
Under individual waivers	1029
Under advance waivers	225
2. Inventions for which waivers have been voided	266

* Statement of Gerald Mossinghoff, NASA Deputy General Council, before the U.S. Senate Subcommittee on Science, Technology and Space, July 23, 1979.

Appendix C

UTILIZATION/COMMERCIALIZATION STATISTICS ON WAIVED INVENTIONS*

Number of Waived Inventions Surveyed:	121
Percent of Total (788) Active [†] Inventions:	15%
Total Number of Responses:	102
Percent Response:	84%

<u>Types of Inventions Surveyed</u>	<u>Reports Requested</u>	<u>Reports Received</u>	<u>Percent Response</u>
Previous Indications of Probability of Use in 1977-1978	100	83	83%
Newly Waived Inventions	13	12	92.3%
Nonresponsive to 1977 Request	8	7	87.5%
<u>Status of Surveyed Inventions</u>	<u>Number of Inventions</u>		
Utilized/Commercialized (First Use-2 inventions)		7	
Development Efforts Continuing		39	
Licensing/Promotion Only		34	
No Further Development Expected		22	
Total Number of Active [†] Inventions (Through 1977):	788		
Total Number of Inventions Voided:	258		
Total Number of Inventions Utilized/ Commercialized:	193 (18.5%)		

* See Appendix B

† Waiver not voided

Appendix D

NASA LICENSING STATISTICS U.S. PATENTS AND PATENT APPLICATIONS December 31, 1978*

U.S. PATENTS HELD BY NASA

U.S. Patents and Patent Applications Available for Licensing	3,512
Employee Inventions	2,378
Contractor Inventions	1,134

NONEXCLUSIVE LICENSES

Licenses Granted to Date	502
Licenses Revoked or Terminated	260
Licenses in Force as of this Date	242
Inventions Covered by Licenses in Force	124

EXCLUSIVE LICENSES

Licenses Granted to Date	21
Licenses Revoked or Terminated	12
Licenses in Force as of this Date	9
Inventions Covered by Licenses in Force	9
Different Licenses	8

* See Appendix B

Appendix E

COMMERCIAL USE OF NASA OWNED INVENTIONS LICENSED BY NASA IN THE UNITED STATES December 31, 1978*

NONEXCLUSIVE LICENSES

Nonexclusive license in force	242
Utilization reports received from licensees . . .	138

POSITIVE USE REPORTS

Reports of commercial use	50
Inventions covered by these reports	34
Employee inventions	28
Contractor inventions	6

NEGATIVE USE REPORTS

Reports of no commercial use	88
Inventions covered by these reports	56
Employee inventions	40
Contractor inventions	16

EXCLUSIVE LICENSES

<u>EXCLUSIVE LICENSES GRANTED TO DATE</u>	21
Employee inventions	14
Contractor inventions	7

POSITIVE USE REPORTS

Reports of commercial use	6
Employee inventions	4
Contractor inventions	2

NEGATIVE USE REPORTS

Reports of no commercial use	15
Employee inventions	10
Contractor inventions	5

* See Appendix B

Appendix F

COMPARISON OF NASA INVENTION COMMERCIALIZATION STATISTICS (Five past studies)

Study	# of inventions waived	# commercialized (%)	# of inventions licensed (# of licenses)	# commercialized (%)
Robert Solo [13] 1966	160	7 (4.4%)	48 (118)	1 (2.1%)
Watson & Homan [14] 1966	189	21 (11%)	47 (108)	5 (10.6%)
Phillip Wright [15] 1974	668	97 (14.5%)	-	-
Kaskovich [16] 1974	333	52 (13.5%)	? (226)	60 (>26.5%)
NASA [17] 1979	1046	193 (18.5%)	-	-

Appendix G

PERSONAL INTERVIEWS CONDUCTED

In order to gain a better perspective on industry's views OF NASA's patent policy, personal interviews were conducted with the owners of several small firms and patent attorneys from several medium and large firms that have performed NASA research in the past. Interviews with the patent counsels from eight Federal agencies (NASA, DOE, DOD, USDA, HEW, DOI, NSF, DOT), the Office of Federal Procurement Policy (OFPP), the American Patent Lawyers Association, Research Corporation, and numerous industry associations were also conducted.

These interviews proved invaluable in providing insight into the industry and Government views of alternative Government patent policies. Findings from these interviews have been included in the report where relevant.

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**Improving NASA's Technology Transfer Process
Through Increased Screening and Evaluation
In the Information Dissemination Program**

by

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PROGRAM IN INFORMATION POLICY

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Summary

This paper focuses on ways to improve NASA's technology transfer system. The analysis in this paper assumes that an improvement of the current status can be achieved if the technology transfer process is better understood. This understanding will only be gained if a detailed knowledge about factors generally influencing technology transfer is developed, and particularly those factors affecting technology transfer from government R&D agencies to industry. Secondary utilization of aerospace technology is made more difficult because it depends on a transfer process which crosses established organizational lines of authority and which is outside well understood patterns of technical applications.

In the absence of a sound theory about technology transfer and because of the limited capability of government agencies to explore industry's needs, a team approach to screening and evaluation of NASA generated technologies is proposed in the analysis which follows. The proposal calls for NASA, and other organizations of the private and public sectors which influence the transfer of NASA generated technology, to participate in a screening and evaluation process to determine the commercial feasibility of a wide range of technical applications.

Introduction

In providing for the widest practicable and appropriate dissemination of information about its R&D activities, NASA faces a task of vast scope and substantial complexity.

In fulfilling its task NASA must solve two complex problems:

o The Information Problem

The secondary utilization of aerospace technology poses a question that is difficult to answer: "How can an unknown target group in industry be provided with a technology having unknown applications?" In order to respond to this challenge NASA must necessarily initiate "horizontal" technology transfer through a communication process which crosses institutional and organizational boundaries. This process is not well understood.

To transfer the right information to the right target group is a difficult task. But, this is only one part of the technology transfer process. Information dissemination is a necessary but not a sufficient condition for technology transfer (see also: Baer et al., 1976, p. 27).

o The Application Problem

There exists a spectrum of potential reasons why industry does not accept a known technology. Technological feasibility is no guarantee of commercial success. Furthermore, new technologies are very often not only market-creating but also market-destroying.

Studies indicate that NASA performs excellent work in disseminating information. That is not to say that there do not exist ways of improving the NASA information dissemination system. In addition, based on an interpretation of investigations performed by the Denver Research Institute, it appears that opportunities for substantial improvement exist in the application process.

Rather than attempting to improve the technology dissemination system through a new kind of technical report, it may be more beneficial to improve the information itself. More potential value could be added to the information system by detailing competitive technologies, by indicating neighboring technologies which already exist, or are developing, by suggesting possibilities for useful applications, and by providing commercial feasibility information. Such activities impact on the application problem in a positive manner (see also: Chakrabarti, 1972, p. 7).

In order effectively to provide this "value added information", one must understand the supply characteristics of NASA technologies, with regard to potential commercial applications and specific demand characteristics of potential users. In addition, one should know about "what is going on" in industry and between industry and government agencies.

How can such a task be accomplished? An important step is to enhance the screening/evaluation process of NASA generated technologies. That is to say, enhancing the ability

to anticipate the future value of a NASA technology and thereby choose an effective transfer medium. Since no comprehensive detailed knowledge about the many facets of technology transfer exists, two possibilities seem worth pursuing in the screening/evaluation process.

o Statistical Analysis

Based on existing historical data, one can try to determine the relevant characteristics of technologies which enhance their value for potential users.

Such statistical analysis could provide substantial insights. Industry, however, frequently reorganizes its structure and changes its needs, so statistical analysis is of limited value. But, statistical analysis might be used for preevaluation, thereby filtering out presumably valuable technologies to be evaluated by a team.

o Team Approach

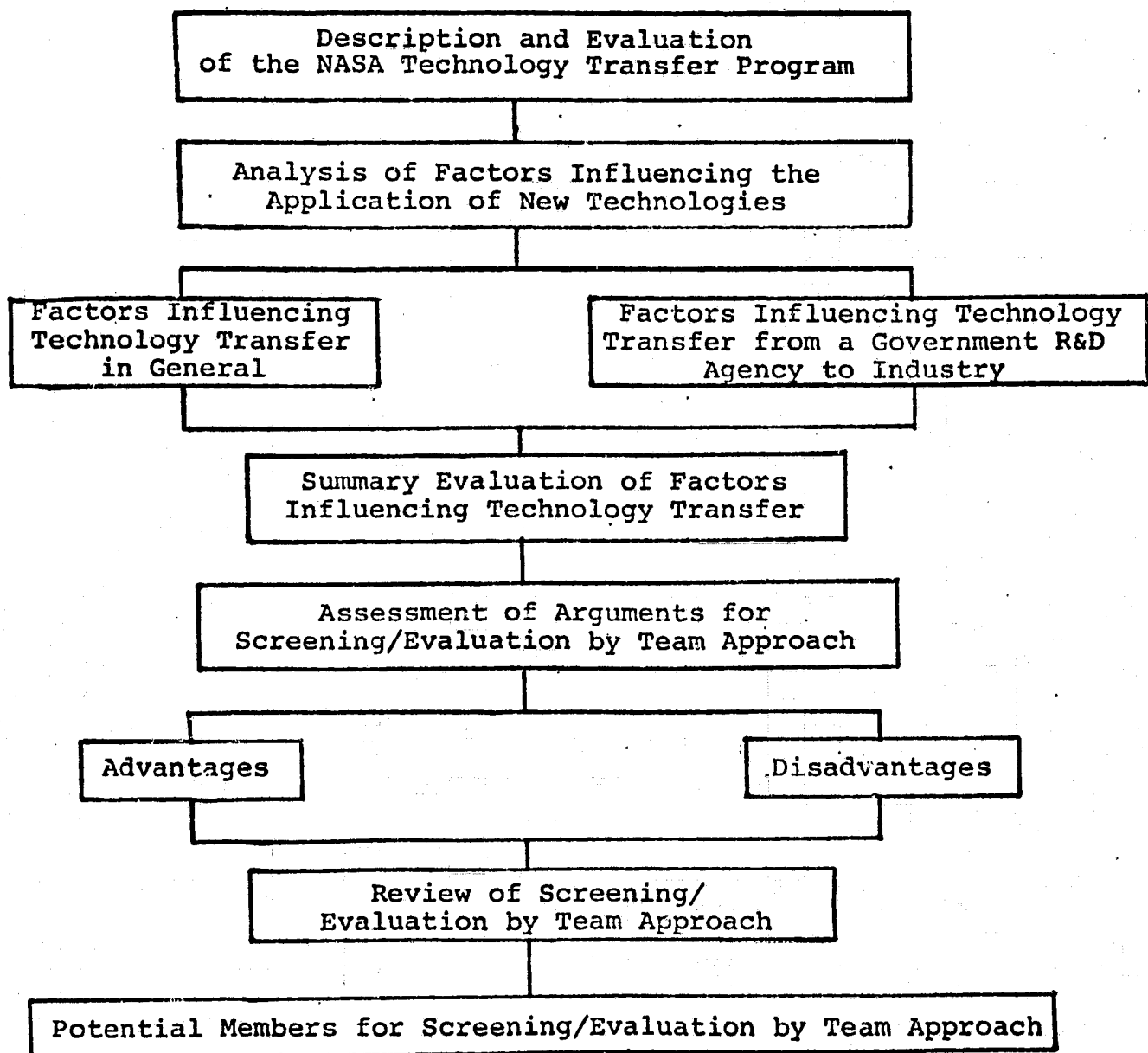
Evaluation using a team approach is suggested here using teams that include members of the user community, such as professional associations, and governmental agencies which are concerned with regulation and commercial R&D. Such an approach would enhance the technology transfer process.

The purpose of this paper is to explore the potentials of a team approach to the screening/evaluation process. This approach creates two substantial benefits:

(i) Given a lack of knowledge about the complexities of technology transfer, this approach could become a powerful tool in overcoming those complexities.

(ii) Technology transfer is important for all members of a society and should therefore not be the sole concern of an R&D agency like NASA. A team approach would promote acceptance of the view that technology transfer is the common responsibility of all participants in the commercial utilization of advanced technologies.

To outline the characteristics of a team approach to screening/evaluation, this paper is organized as follows:



In the first section below, the NASA information system is described and evaluated. This evaluation suggests that NASA improve the information itself rather than modifying the information dissemination system.

An assessment of factors which are likely to impact on technology transfer is made in the second section. At the end of this section, improvements achievable using a team approach are discussed.

The third section assesses arguments for a team approach to screening/evaluation.

Potential members of a screening/evaluation team are noted and their capabilities explored in the fourth section.

1. Description and evaluation of the NASA Technology Transfer Program

The NASA Technology Transfer (TT) program consists primarily of Information Dissemination, Application Teams, Information Dissemination Centers, and Applications Engineering. For the purpose of this paper, this transfer system is viewed as three phases:

INFORMATION PHASE

- o library service
- o delivery service (technical reporting)

MARKETING PHASE

- o identification of potential users' needs
- o identification of technologies matching users' needs

APPLICATION PHASE

- o demonstration projects
- o reengineering projects
- o production of marketable products

The development of the process can be thought of as an evolution. In its information phase, information is provided for the users. In order for technology transfer to happen, the user must play an active role. NASA's role is more passive, once information has been made available. The library service, for example, consists of a set of interrelated services. In the literature search service ("remote") the user is active; he defines key words which are used for information retrievals performed by Industrial Applications Center's (IAC) personnel. The next extension is an interactive retrieval service (on-site); the user sits beside the "Information Specialist," who now plays an active part due to his knowledge about the NASA data base. He is able to identify keywords the user might never think of. In a current awareness search service (periodical reports which supply the user with up-to-date information in his field of interest, generally delivered on a monthly basis), the user defers to the search service totally. NASA's role is more active in cases where the user requests interpretative services and NASA participates in the exploration of the retrieved information.

Staffed with highly qualified scientists and engineers, Industrial Applications Centers provide not only information but potential applications of information. An IAC's staff

personnel may initiate contact between a requester and companies, universities, etc., already working in a certain field.

In the marketing phase, performed by State Application Centers and Technology Application Teams, NASA takes a more active role: exploration of a user's needs, search for a technology which will match those needs and then implementation and commercialization of the technology (see Anyos et al., 1978. p. iii). In the application phase, NASA reengineers technologies in order to bring them closer to commercial feasibility.

Studies investigating the benefit-to-cost ratios concerning the main elements of the NASA Technology Transfer program show a positive relationship. The aggregate benefit-to-cost ratio was estimated to be 6 : 1. The single elements of the program are characterized by ratios lying in a spectrum 3 : 1 to 26 : 1 (Johnson et al., 1977b, p. v, vi). For each dollar NASA invests in its TT Program, benefits equivalent to six dollars are produced.

When interpreting these numbers, one must take several factors into account. First, such benefit-to-cost ratios cannot be directly compared with those of other NASA projects. Of course, the ratios calculated for the NASA TT program do not reflect the investment in developing the technology. Second, each NASA contractor must write a contractor report, which can be thought of as an initial step toward producing an information product, the costs of which are not covered by the TT program.

In assessing possibilities for further improvements of the TT program, an analysis of the NASA Tech Brief Program, under-

taken by the Denver Research Institute, is most valuable (Johnson et al., 1977a, p. 36). They classified TT applications in four modes:

- mode 0 no application at all
- mode 1 used for information only
- mode 2 used to improve already existing production technologies, products and services
- mode 3 used to develop new production technologies, products and services

The probability for any of the individual modes occurring were calculated as follows:

mode	probability
0	34%
1	54%
2	11%
3	1%

The 54% for mode 1 indicates that NASA is providing an excellent information service. There is no other information service available which covers the aerospace area and related fields in such a comprehensive way. This is true partly because the NASA data base includes information produced by other organizations. For example, due to a special information exchange agreement between the NASA Scientific and Technical Information Office (STIO) and the European Space Agency (ESA), a user can obtain the latest international developments in this field.

The results of the DRI study show a very different picture concerning the development of new products from NASA technical

information: "Successful efforts to develop new products from TSP's have occurred but they are exceptions. More typically, such attempts lead to a new financial loss for the TSP requester. Even for successful Mode 3 application (development of new technologies, products, services), the TSP information is usually a minor technical input (about 5 percent) to the new economic activity" (Johnson et al., 1977a, p. 48).

At the present time, it seems that the most positive outcome of NASA's TT program is that the information about its technologies is available promptly and comprehensively.

The calculated net benefit for the Industrial Application Centers is moderate compared to those of the technical reporting program. One might expect the contrary, due to the comprehensive and thorough services provided by IACs. Moreover, it is important to emphasize that while technical reports are free, users are charged for the services of the IACs. The benefit-to-cost ratios currently available may not describe the true picture. Out of a vast set of new technologies, most will have little or no impact on new products and services. There is a small subset of technologies which are, unexpectedly, so successful that they pay for the whole R&D program of an organization.

To enhance the effectiveness of NASA's TT program, it would be useful to know about the underlying factors which influence technology transfer. For example, it is not particularly useful to calculate time-lags between the technological feasibility and the first commercial application of a technology;

indeed, those calculations show substantial variations (see: Rosenberg, 1976a, pp. 72-74). There are many different factors at work and without a detailed understanding of those factors it is hard to initiate efforts to make technology transfer more effective.

NASA technology has the potential to improve existing technologies and to develop new production technologies, products and services. However, an improvement of the technology information dissemination system by itself is not likely to lead to a substantial change. Producing and reproducing information about a technology where there are barriers in the application of this technology is not likely to lead to better results. In one case hundreds of TSPs were requested regarding a new gas turbine seal, but there were no applications because no firm was willing to take the necessary substantial commercial risk. If a procedure existed, e.g. a team approach to screening/evaluation by which NASA anticipated such a problem, NASA could offer more help. For example, where potential users of a new technology such as governmental organizations are identified, NASA might develop a prototype if the technical risks were so high as to inhibit further development.

The key for solving the applications problem is a mechanism which enables NASA to explore the potential commercial environment for a certain technology which is announced through the TT program. This is the underlying basis for the suggestion of technology screening/evaluation using a team approach.

2. Analysis of factors influencing the application of a new technology

Technology transfer is a complex process which is not well understood (Hoelscher, Hummon, 1977, p. 76), especially horizontal technology transfer or secondary utilization. There may be hundreds of potential secondary applications of aerospace technology, but it is extremely difficult to identify them. Indeed, it might be difficult to think of any useful applications of a new technology at all. Thomas Edison is reported to have thought that a phonograph would be used to record the wishes of dying men (Rosenberg, 1976a, p. 197).

In the secondary utilization of aerospace technology, it is often remarkable how remote the secondary utilization is from the original space application. A joint NASA/military project on helicopter rotors produced a vibration dampening technology, now used in building guitars (Haggerty, 1978, p. 34).

In anticipating secondary utilization one faces an "open-end" problem. There will never be a method for identifying all the possible or useful non-aerospace applications of a NASA technology. "It is important that one never knows in advance if spinoffs will occur, or what their benefits may (or may not) be. Because of this uncertainty, spinoffs are nothing to bank on." (Thurow, 1978, p. 69.) It might be worthwhile to initiate a potential applications "creativity-session" for selected technologies. Such value added to a purely technical description of a new technology might enable a reader of a TECH BRIEF to envision many possible applications and ultimately to develop a useful application.

Before one explores the potential value of a technology, an idea for the application of that technology is necessary. One can then begin to assess the impacts of factors influencing the technology transfer process. A knowledge of such factors and their impacts on technology transfer is important in estimating the probability of an industrial application of a technology. In the following paragraphs some of those factors are discussed.

2.1 Factors which influence technology transfer.

The following section describes some factors which generally influence technology transfer as well as specific factors which influence transfer from government R&D agencies to industry.

o All technologies have certain characteristics making them advantageous for some applications and useless for others.

The application of numerical control in the machine tool industry is not economical for long production runs. Other factors like preparatory and maintenance work have to be taken into account, especially if a skilled work force is scarce. (see also: Ray, 1969, p. 58). One must also check the impacts of a new technology on the organization of the whole production system. This is extremely important in industries like the chemical industry which is characterized by close and interdependent relations between materials, energy and information flows. Often, a new technology - even if only a small piece - can only be used advantageously if the whole production system is reorganized. If the investment expenditures for the re-

organization are greater than the anticipated cost reductions caused by the use of the new technology, the latter will be ignored.

It is extremely difficult - if not impossible - to detail the general characteristics of technologies, due to the fact that production systems differ from industry to industry and even within a certain industry. Quite a few mathematical models have been developed to describe the behavior of an industry, e.g. the oil industry. But the value of those models for the explanation of industry's behavior concerning the adoption of new technologies is only moderate (Lapple, 1978, p. 284). Assume that there are two different technologies for the production of a certain product, one of which is relatively more energy consuming than the other one. Without specific knowledge about the production system of a firm, there is no way to anticipate which of the two technologies will be applied. For example, the more energy consuming technology might produce valuable by-products which far outweigh the cost advantages achieved by using the less energy consuming technology.

In the screening and evaluation of NASA generated technology it is valuable to know about the factors described above. It is extremely difficult to achieve such detailed knowledge on an industry by industry basis. In this context, technology screening/evaluation using a team approach would be a valuable asset in gaining knowledge about those characteristics of specific technologies which are relevant to the technology transfer process.

o The degrees of technical and business alignment between industries is an important parameter in the technology transfer process. It is reasonable to assume that the less alignment between industries exists the less likelihood there is of successful technology transfer between industries, and the more important technology transfer programs become in promoting the transfer process (see also: Kottenstette, Rusnak, 1973, p. 106). Therefore, knowledge of the degree of technical and business alignment between industries is essential to planning technology transfer programs.

o Due to the fact that each field in science and technology has developed its own information channels and has created individual problem solving methodologies, there exist interdisciplinary barriers. Normally, people not trained in a special field are unable to communicate with people who are. The party unable to understand a certain professional language may be unwilling or unable to learn this language. Consequently, there exist barriers between fields in science and technology. The difficulty of overcoming interdisciplinary barriers can be assessed by analyzing an interdisciplinary field. In the American Journal of Operations Research about 10% of published articles are of interest to a special target group but actually only 2% to 4% reach this target group (see: Pierskalla, 1979, p. 8) due to "language" problems.

Of course, to overcome those problems specialized journals can be issued. The Operations Society of America is doing this,

for example, by issuing the Journal of Transportation Science. Within this Society there are plans to pursue this approach in other areas by issuing journals on such topics as public systems and marketing (Little, 1979, p. 4). NASA uses a similar technique when it issues bibliographies in areas such as Aerospace Medicine, Biology, Earth Resources, and Energy.

This approach, issuing journals in selected areas, has limited advantages. It is impossible to issue journals in all areas of potential interest and, furthermore, people are often reluctant to use new journals.

A different approach could be adopted. Rather than issue journals, it is possible to develop close relationships with societies already covering a certain field and publish articles in established journals. A team approach to technology screening/evaluation is based upon strong relationships with organizations which cover different areas in science and technology. Doors to these areas would then be opened.

o Estimation of the relative efficiency of a new technology in comparison to already existing ones is an important factor to take into account. Often a new technology offers few or no advantages in terms of technical and cost aspects when compared to those already in use (see also: Cooper, et al., 1973, p. 56). Sometimes engineers need a substantial amount of time to find out efficient ways to operate a new process. This is particularly true for chemical process industries due to the absence of a comprehensive understanding of the production process in many cases.

Often, technologies already in use experience substantial improvements when a new technology is expected to enter the market. For example, the slow diffusion of the steam engine in the United States was caused by improvements in water wheel technology (Rosenberg, 1972/73, p. 24). Estimation of "switch-over-points", and the efficiency curves, of old and new technologies is a difficult task. In most commercial enterprises, it is rare that a new technology can be used with great success immediately. This situation delays the use of a new technology. The knowledge of this delay is of major interest due to the fact that the new technology might itself become obsolete prior to implementation.

o In some cases one would fail in judging the value of a new technology without analyzing its "neighboring" technologies. To some extent, each technology is dependent on other technologies. For some new technologies, essential neighboring technologies might not be available. Consequently, one must overcome numerous bottlenecks (Rosenberg, 1976, p. 125). Often, efficient technologies cannot be used because "parallel necessary technology did not arise elsewhere." (Locke, 1978, p. 25.) It takes time to make neighboring technologies available due to the fact that 6 to 10 years are often required to develop a process from pilot stage to industrial scale. If such bottlenecks are anticipated, one can initiate appropriate steps to make the new technology more readily available for applications in the commercial area.

o In almost all cases production technology is capital-intensive. If an industry is dominated by a small number of

big firms, they might agree to ignore a new technology in case it would cause a major impact on existing production technology. A study of Du Pont Rayon Plants points out that delays in applying new technology stemmed from the fact that the new technology required new investments (Hollander, 1965, p. 199). If capital goods already in use are relatively new and characterized by long lifecycles, the long-run cost advantages of a new technology might be outweighed by short-term financial returns (Ray, 1969, p. 45).

The behavior of the American steel industry in the fifties can be cited in this context. Although the oxygen furnace process had proven superior to the open-hearth process in Europe (Gruber, 1969, p. 43), the U.S. Steel industry switched over to the oxygen furnace process relatively late. The capital intensiveness of the production technology seemed to be a major reason for this delay (see also: Gruber, 1969, p. 49, 50). A spokesman for the U.S. Steel Corporation said that: "Nobody who has efficient open-hearth furnaces is going to throw them out to buy oxygen furnaces. We waited until we needed to replace old capacity." (in: Ray, 1969, p. 45.)

On the other hand, if a new technology is able to overcome bottlenecks in an existing production system and thereby offer incremental change compatible to the existing technology, it is likely that such a technology would be used immediately. An investigation performed by Wright points out that industry's interest regarding those NASA generated technologies offering improvement on existing technologies was nearly eight times

greater than industry's interest in technologies not compatible to those already in use (cited in: Chakrabarti, 1972, p. 7).

o An important factor in technology transfer is the comparative advantage a firm gains in using a new technology. In judging contractual arrangements one should take into account that "the smaller the variation in comparative advantages among prospective innovators of the same idea the less will the exclusive right to invent be worth, even if the returns were fully capturable" (Cheung et al., 1976, p. 19).

Regulations requiring mandatory use "of the best available technology" are also an important consideration. In a case where a new technology will turn out to be a "best available technology," an innovator will not enjoy a comparative advantage due to the fact that other firms are forced by law to follow. Furthermore, other firms then have an incentive to hinder potential innovators (Hill, 1975, p. 139).

Another case to consider is a major change of the production technology in an entire industry branch. At present some 80 percent of products in the chemical industry depend on oil. To switch to coal, major changes must take place. If one firm goes ahead, it will face tremendous risk. Other firms, choosing the "second is fastest" strategy, would gain technical knowledge by monitoring the research work of the innovator (Thurow, 1978, p. 70). They will follow only if it is economical to so do. The first firm may not gain substantial comparative advantages. If one is able to anticipate such factors, one

can arrange appropriate steps, for example, joint projects between NASA and all major firms within an industry branch, or an industry association.

o New technologies are both market-creating and market-destroying. Market-destroying effects will be greater the more existing technology is integrated into the production system. It is important to realize that it is insufficient to assess those effects only at the firm level. For example, replacement of pesticides might impact the cosmetics industry because both industries use common raw materials. Also, restrictive sulphur emission standards caused oil companies to develop technologies to produce sulphur out of their residuals. Consequently, medium-sized firms which produced sulphur out of elementary sulphur were nearly eliminated. Finally, West Germany experienced labor strikes due to the introduction of text processing technologies. Printers were frightened of losing their jobs overnight.

Attempts of oil companies to achieve control over competitive uranium and coal technologies "may be seen as attempts to assure long-term market control by minimizing the potential threats arising from technological breakthroughs in the provision of substitute products." (Rosenberg, 1976b, p. 533). A recent example is the behavior of the electric utilities towards solar power due to the fact that such a decentralized energy source does not fit the structure of existing centralized power line networks (Commoner, 1979, pp. 69-71).

Those examples clearly show that the market-destroying effects of a technology may lead to the non-application of a new technology or at least a delay in the diffusion process. In assessing the value of a new technology, it is important to keep in mind that it must "become an element of the socio-technological fabric" (Hoelscher, Hummon, 1977, p. 78) and for a firm "of the various kinds of environmental change, few are more pervasive or important than technological change" (Cooper et al., 1973, p. 54).

o Regulation is an important factor to take into account.

A major influence is expected from regulations implemented in the form of so-called design characteristics. A firm may feel it is inconvenient to try to change governmental rules for the benefit of a minor improvement and thereby will not use a technology which only leads to moderate benefits.

However, careful analysis can help anticipate industry's behavior. Regulation causes technology arrestment as well as technological advance. One of the industries most affected by environmental regulation is the chemical and allied products industry. This industry claims that this kind of regulation leads to a decline in capital productivity due to the fact that investments for reduction of emissions decrease the amount of capital used for the production line. This argument holds true, but only assuming that no technological advances are made. Indeed, under this assumption a substantial quantity of capital has to be invested for the treatment of residuals without any benefit for the production processes. An investi-

gation performed in West Germany (Meissner, Hoedl, 1978) showed that industry has strong incentives to change this "unpleasant" situation, and one efficient means to do so is to change the production technology. In this case, regulation caused a need for new technologies. In general, only detailed analyses will lead to a well balanced judgement about the impacts of regulation on technology transfer.

o Another extremely important factor is the relation between the development of a technological innovation and the development of the diffusion process. It seems reasonable to assume that industry will slow down the adoption of new technologies if the speed of innovations is high. This assumption is based on the fact that firms face the danger of investing in "soon-to-be-obsolete technology." (Rosenberg, 1976b, p. 534.) While such a pattern might be characteristic of a lot of cases, it does not hold for all. In the computer industry, important innovations are characterized by a diffusion time of 3 to 5 years; innovations of less importance are delivered to the market within 1 year. Firms must be heavily active in R&D in order to achieve a competitive position in the market (Dunn, 1979, pp. 3-4).

Competition is a strong force in promoting the application of new technologies (Gruber, 1969, p. 40). In assessing rates of innovation and diffusion, competition should be taken into account.

o Dependent on its stage of development, a firm shows different responsiveness to different kinds of innovations.

Utterback offers the following model for explaining this phenomena (1976, p. 36):

During the first stage, development is based on product change primarily. Consequently, product innovations have priority over process innovations. Based upon experiences, e.g. in the semi-conductor industry, firms concentrating on process innovations in this early stage face the danger of improving the production-technology of a product which soon becomes obsolete.

The second stage finds established firms in an industry looking for process innovations. These small changes, compatible with the existing production system, reduce costs of existing products.

In the last stage, established firms have an incentive to delay major technical changes because the inflexibility of capital-intensive production systems. It might be possible to obtain such knowledge by monitoring the development of an industry.

Those factors influencing technological change mentioned above provide a few hints; the list is neither complete nor exhaustive. Yet, the rather brief discussion showed the importance of those factors and the difficulty of exploring their impact on technology transfer. To make technology transfer more effective, however, knowledge about such factors seems to be essential (see also McClain, 1976, p. 116). Therefore, I will now explore the impacts of such factors on the secondary utilization of aerospace technology. Anticipation

of those impacts is a necessary condition for choosing appropriate steps in "putting technology to work."

2.2 Factors influencing technology transfer from a government R&D agency to industry.

The factors discussed above are generally important. Those factors analyzed in what follows are of particular interest if the transfer process takes place between a governmental agency to industry. The analysis will focus on such factors important to NASA's TU program.

o For the successful introduction of a new technology the relation between innovation and innovator is most important. Therefore, many firms have adopted a procedure whereby the innovator becomes the product manager for his own product. This reflects the fact that an innovation needs a key individual who pushes it from innovation to commercialization. An empirical investigation of NASA generated technology further points out that the involvement of the innovator in the usage of the innovation is important for success (Chakrabarti, 1972, p. 28). Furthermore, an investigation of federally funded demonstration projects showed that in cases where the project initiative originates from nonfederal sources, the diffusion process is better than projects initiated by a federal agency (Baer et al., 1976, p. 48).

o Psychological barriers to the use of government information and technology and, to some extent, the restricted availability of government information must be taken into account. Up until now industry has hesitated to use govern-

mental information and technology. There is - justified or not - a concern that government might try to influence its activities or at least monitor requests. This problem is reinforced because NASA's data base is not as easily available as other federal data bases. But it seems likely that such barriers can be overcome. A DRI study points out that users, if they have once used NASA services successfully, are likely to do so in the future. A review of the number of users of NASA's data base, appears to show an educational process taking place.

Concerning the restricted availability of NASA literature, it is worthwhile to think about improvements. It normally takes a user 1 to 2 weeks to receive the printouts of a literature search service. The information is rarely published in widely available professional journals. Instead it is published in NASA journals which are in most cases only available in NASA Centers and through the National Technical Information Service. Consequently, it takes at least one to two months before a user receives the information.

Further, it might be valuable to improve the "On-Site" literature search service. An intelligent user should be able to screen the information while sitting at the terminal; under current conditions, it is too time consuming to do so. To improve the procedure, "touch-panel" terminals could be installed at the Industrial Application Centers. Those industries remote from the aerospace industry are more likely to be attracted if access to NASA information is made easier.

o The value of NASA generated technology is of critical importance. NASA's philosophy - especially that of the IAC's - that it is wasteful "to reinvent the wheel". - is often not accepted by industry regarding NASA generated technology (see e.g. Olken, 1972, p. 617). It has been argued that NASA technology is the result of reorganizing what was already at hand, that is to say NASA technology lacks novelty. Miniaturization was a new concept in the sixties but is now a well-known design technique. In general, government information is characterized by the label: too much, low value.

To counter such labels, many factors must be explored. At first, it is quite natural that "massive-mobilization R&D projects" (Thurow, 1978, p. 30) like Apollo and the Space-Shuttle can be successfully performed only if the basic knowledge about the technologies employed already exists.

This means that NASA technologies are in a much more advanced application stage. This should not be confused with the value of such technologies. This situation reinforces the need to develop a technological classification scheme which separates basic knowledge, engineering-application knowledge, etc. This classification scheme would enable NASA "to shoot" at appropriate target groups with efficient transfer mechanisms. It is extremely important that a rapid transfer of engineering-applications take place due to the fact that such knowledge rapidly becomes obsolete. In such cases, it is not a question of technological availability but of whether the technology is known to all potential users. This leads to a second

important fact. A certain technology might be well-known; a special technique might be general knowledge in one industry, but there is no way to know if this knowledge is available to other industries as well. Vertical technology transfer, a process within one industry, works quite well. In contrast, there are no established mechanisms for horizontal technology transfer, a process which takes place across organizational and industry borders. Kottenstette and Rusnak describe this three caveats (1973, p. 106):

- (i) "Firms have varying degrees of technological alignment with aerospace and their relative alignment is of primary importance in effecting secondary utilization."
- (ii) "Increased distance from the aerospace sector (less alignment with aerospace) decreases the likelihood of new technology adoption through diffusion."
- (iii) "Increased distance from the aerospace sector implies that a planned effort is required to provide access to the aerospace technology."

Communication between firms is important to the transfer of technologies (see Utterback, 1971, p. 82, 83). To estimate the value of aerospace technology for other industries, one might use an "alignment structure" plan: (described below) and organize transfer efforts around such a plan.

Such an alignment structure plan can be illustrated in the form of a graph or a matrix which describes relations between firms. Such an approach was used by Czepiel (1975) to explore the diffusion of the continuous casting process in the steel industry. The arcs in the graph or the elements in the matrix, represent two kinds of flows, material and information. It is valuable to consider firms and other organizations

of the private and government sector which influence the technology transfer process. That is to say, the alignment structure plan should represent the entire "technology delivery system." The main components of a technology delivery system are: source of R&D funding, R&D performers, material supplier, manufacturer of the capital goods, producers of the product, distributors, ultimate users (see also: Yin, 1978, p. 13).

In exploring the value of NASA technology for industry one should keep in mind that this technology has been developed for NASA mission-oriented R&D projects. This is to say that the technology is not developed in a commercial environment. There is a trend, as in the military field, to produce such technologies as soon as it is technically feasible. Technical feasibility is no guarantee of commercial success. Of course, there are a lot of fine, commercially successful technologies, like integrated circuits, jet airplanes, etc. But there are other cases, like the nuclear driven ship.

To sum up, estimating the value of NASA technology is not easy; it requires knowledge or at least three primary components. First, the stage of technological development, from vague ideas to prototypes. Second, the relation of other industries to the industry generating the technology. Third, the commercial "shape" of the technology.

o Aside from the specific value of NASA generated technology the value of externally generated information about technologies in general has to be taken into account. Many firms believe that externally generated knowledge, when compared to its own R&D, is not as unique as is often claimed (VDI, 1979, p. 18). It is important to realize that in any case the firm must check the information. As a result, the value of a Tech Brief is known to a firm only after a check of its content, that is to say after the firm has invested time and money (Johnson et al., 1977a, p. 11).

Refusing to adopt externally generated technology seems to be typical of U.S. firms, at least when compared to firms in Japan and West Germany. There is some feeling that "an overall increased sensitivity to and utilization of outside technology must be developed..." (Gee, 1978, p. 212). In general, such behavior is caused by factors described in the previous section. For example, in chemical industries there are huge and complex integrated production systems. The change of one element might impact on many other elements. Therefore, incremental improvement is typical; major changes of the production technology tend to be delayed. Major new technologies are often created outside the established firms but are, in many cases, neglected due to the large capital investment in existing technology (see also: Abernathy, Utterback, 1978, p. 41). Firms in the U.S. have also been reluctant to undertake cooperative programs. While these

programs are quite common in Europe only a few exist in the United States (U.S. General Accounting Office, 1978, p. 58). In the future this problem might be partly eliminated. The experience of MIT after working with industry under a NSF grant for several years indicates that once firms "enter into cooperative research, they discover that it does not threaten their competitive position" (U.S. General Accounting Office, 1978, p. 60).

The factors discussed above are only a few out of a large set. It is not intended to provide a complete list. An attempt was made to demonstrate that government R&D agencies face specific difficulties in promoting technology transfer, difficulties which add up to those confronting technology transfer in general.

2.3 Summary evaluation of factors influencing technology transfer.

After having discussed factors influencing technology transfer in general and in particular those factors influencing transfer from a government R&D agency to industry, a short summary is provided in the following:

<u>Factors Influencing Technology Transfer in General</u>	<u>Factors Influencing Technology Transfer from Government R&D Agencies to Industry</u>
o relative efficiency of new technologies compared to those already in use	o psychological barriers to use of government generated information and technology
o availability of neighboring technologies	o value of NASA generated technology to industry
o capital intensiveness of new technologies	o relation between innovation and innovator

Factors Influencing Technology Transfer in General (Cont'd)

- o comparative advantage achieved by the entrepreneur
- o market-creating and market-destroying characteristics of new technologies
- o interdisciplinary barriers
- o technical and business alignment between industries
- o major changes of the production technology in a whole industry branch
- o regulation

All of these factors may influence technology transfer in a negative manner--at least to delay the adoption of a new technology. Therefore, to solve the application problem described in the introduction of this paper, it would be extremely useful to explore NASA technologies with regards to such factors. If the results of such investigations are added to information about a certain technology, benefits might be achieved. In case a new technology is announced by NASA, it might be useful to know to what degree this technology fits current industrial patterns. One can identify material suppliers, producers of equipment, etc. which are able to supply the technology. Such knowledge - gained by exploring factors influencing the transfer process, - provides a basis from which to choose the right steps to put a technology to work. To some extent such value-added functions are performed by

staff members of the Industrial Application Centers. Users of the IACs' services can be directed to other organizations working in a certain field. Furthermore, staff members of the IACs provide valuable information concerning market analyses. In order to realize a real breakthrough in technology transfer such services should be provided on a comprehensive basis.

Under current conditions the screening and evaluation process concerning the Tech Brief is performed mainly by the Technology Transfer Officers at the single NASA Research Centers in conjunction with the Illinois Institute for Technology Research Institute. The screening/evaluation process employs the following criteria:

- o marketing potential
- o novelty
- o technology
- o nonaerospace potential

If an in-depth analysis of the factors influencing technology transfer is performed, it is likely that procedures can be developed providing for substantial improvement in the screening and evaluation process. Concerning the screening and evaluation criteria of "marketing potential," the following procedure might be developed.

o Marketing Potential

Market Destroying
Effects

- o Identification of already existing technologies to be replaced in part or in total.
- o Anticipation of improvements of technologies to be replaced.
- o Relative efficiency of existing and new technologies over time.

Market Destroying
Effects (Cont'd)

- o Estimation of future rate of innovations concerning the new technology.
- o Necessary reorganizations of existing production systems to integrate the new technology.

As mentioned before, new technologies are both market-creating and market-destroying. The market-destroying effect is important in the development of market potential estimates. First, existing technologies which are likely to be replaced in whole or in part should be identified. In many cases those technologies already in use undergo substantial improvements if a new technology is expected. Therefore, such improvements should be anticipated. Such investigations establish a comparison of the relative efficiency of the technologies already in use, and the new technology to be introduced. This relative efficiency is one of the important decision criteria in determining if a new technology will be used. Furthermore, the potential for further technological innovations should be checked due to the fact that industry is reluctant to invest in soon-to-be obsolete technology. Also, necessary reorganizations of existing production systems in order to integrate the new technology should be considered.

The information dissemination process might be made more effective if the dissemination strategy were based upon a structure alignment plan which indicated to what extent organizations influencing technology transfer are linked together.

After discussing a screening and evaluation procedure which takes into account factors influencing technology transfer,

I will undertake an analysis of policy options to enhance technology transfer.

Technology transfer has often been described as "technology push" or "demand pull." Most empirical studies point out the superiority of demand pull. However, R&D agencies, like NASA, are likely to push technologies. New technologies need pushing in order to overcome barriers, especially in early transfer phases. Often R&D agencies fail to push a new technology when industry has a need for it. In exploring factors influencing technology transfer, as mentioned before, NASA should incorporate industry's needs in its information dissemination policies. The outcome of this approach would be a mixed policy, linking technology push and demand pull. This approach is in line with recent findings. An investigation performed by Mowery and Rosenberg (1979) provides an in-depth analysis of eight of the best known empirical studies on technological innovation which all support the demand pull policy. The authors of the investigation, in analyzing these empirical studies, claim that "the role of demand has been overextended and misrepresented, with serious consequences for our understanding of the innovative process and of appropriate government policy alternatives to foster innovation" (Mowery, Rosenberg, 1979, p. 3). In the conclusion of their study, the authors point out:

The existence of an adequate demand for the eventual product is, of course, an essential--a necessary--condition. But, we suggest, the demand pull approach simply ignores, or denies, the operation of a complex and diverse set of supply side mechanisms

which are continually altering the structure of production costs (as well as introducing entirely new products) and which are therefore fundamental to the explanation of the timing of the innovation process.

At a more general level, the conceptual underpinnings of the "demand-pull" case are perhaps even more fundamentally suspect. Rather than viewing either the existence of a market demand or the existence of a technological opportunity as each representing a sufficient condition for innovation to occur, one should consider them each as necessary, but not sufficient for innovation to result; both must exist simultaneously. (Mowery, Rosenberg, 1979, p. 57.)

In sum, successful technology transfer must be based upon both technology-push and demand-pull (see also: Hoelscher, Hummon, 1977, p. 82; Gilpin, 1976, p. 170).

As such, NASA might consider the "timing of publishing." To push a new technology at a time when industry has an urgent need is likely to product more success than announcing a new technology at any time. An empirical study of NASA generated technologies published in a TECH BRIEF points out, that "the degree of urgency of the problem to which the technology was related seemed to be an important factor..." (Chakrabarti, 1972, p. 162). At a time of low gasoline prices, where no substantial change is expected, it is not appropriate to push electrical automobile engines. But when gasoline prices are increasing, industry might well be responsive.

Of course, one might argue that it is not NASA's task to explore industry's needs and that NASA should announce new technologies when they are produced, making sure that the information can be retrieved by industry at any time. Nevertheless,

hitting the right target group at the right time with the right information might lead to more effective technology transfer and "timing of publishing" might be a method worth consideration.

In general, incorporation of users' needs in policies for technology transfer is essential. This kind of approach is now commonly employed by R&D funding organizations (Yin, 1978, p. 12, 13); NASA's TT program is an example. It is not a question of whether or not a government R&D agency (like NASA) should employ such an approach, but rather it is a question of how to implement it.

3. Assessments of Arguments for a Team Approach to Screening/Evaluation

3.1 Advantages of a team approach to screening/evaluation

The objective of this discussion is to describe possible positive effects on the technology transfer process of technology screening/evaluation using a team approach.

o One main advantage of screening and evaluation by a team of industry/government individuals is that this approach may come to grips with everchanging factors which influence technology transfer. The discussion in previous sections has outlined the difficulty of determining which factors influence (positively or negatively) technology transfer. Furthermore, unlaying cause-effect relations are not constant but change

over time and are difficult to anticipate. The author of this paper assumes that a complete understanding of the factors influencing technology transfer will never exist. This is probably the main reason that the vast number of empirical studies on technology transfer have provided only limited help to policy makers formulating policies to enhance technology transfer.

However, an effective transfer system should allow a rapid check of which factors influencing technology transfer are relevant--even in a time of rapidly changing cause-effect relations--and thereby make possible the choice of an effective transfer mechanism. A team approach might fulfill this task because organizations influencing the technology transfer process would participate in the screening and evaluation process. Thus, the opportunity for all relevant information to be promptly available exists. For NASA this approach would provide a valuable opportunity to ask "what-if" questions of extremely knowledgeable and technically capable partners.

o Assuming that other organizations joined the screening/evaluation process, it is likely that a balanced assessment of the potential value of NASA generated technology would be possible. Furthermore because most NASA technology is produced under relaxed commercial restrictions, and because technological feasibility alone is no guarantee that a certain technology will be commercializable, industry hesitates "to pick up" such technologies.

Also, shortcomings in technology transfer occur because potential users lack relevant information concerning commercial feasibility (Udell, Johnson, 1978, p. 177). With the help of other organizations, NASA might be able to provide such valuable additional information and thereby increase the probability of successful transfers.

o An important "by-product" of a team approach to screening/evaluation would be access to other transfer mediums. In case a professional society participates, one might think of announcing NASA generated technology in a variety of ways:

- in a professional society journal
under NASA's name
anonymously

as a standard publication
in an "innovation column"
- in a journal issued by both NASA and the professional society, etc.

There are many possibilities. The outcome of such options would be (amongst others):

- a higher reputation for NASA technology because the reader will consider NASA information as competitive with other information announced by a professional society
- better access to NASA information

Concerning access to NASA information, it was mentioned previously that under current conditions NASA information is not that easily available to a potential user. Most information is only published in NASA journals, such as contractor reports, and it often takes a month or more to receive them. That is too long a time lag for serious inquiries. In contrast, professional society journals are available everywhere, and it is

likely that a potential user of NASA generated technology would be a regular reader of such journals.

Further, technical information is only one factor in stimulating technological innovation. Education, training and experience also play an important role in that they prepare target groups for new technologies (Utterback, 1971, p. 80). If universities and professional societies join the screening and evaluation process, it would create an opportunity to disseminate NASA generated technology by means of training and education. In the long run this might lead to a substantial increase in technology transfer. To sum up, NASA technology could be disseminated on a much wider basis using existent and effective non-NASA channels.

o It is possible that the screening and evaluation process itself, through the participation of other organizations, would become a transfer process. This is particularly true when so-called industry "gatekeepers" join the screening and evaluation team (see also: Utterback, 1971, p. 64). This characteristic of the team approach is of substantial importance. Several studies point out that oral communication is an effective means for the transfer of innovations because it provides rapid feedback communication (see: Tushman, 1978, p. 625). However, along with this benefit, there is the possibility that NASA might lose some control of the transfer process.

o Technology transfer is a national goal and is not the exclusive responsibility of any government R&D agency alone. The aim of the transfer process is to improve the nation's

economy and is therefore the joint responsibility of all societal groups. Participation of other groups should not be judged as a shortcoming within NASA, but rather as a constructive means to enhance technology transfer.

o Concern about competition between government R&D agencies and industry is frequently mentioned. It is argued that national laboratories engage in "research on technology of commercial significance and thereby directly compete with private industry" (Hollomon, 1979, p. 39). For instance, the McNeil-Schwindler Co. protested NASA's maintenance work on NASTRAN (A NASA computer program), claiming that such work should be performed by private software houses. Evidence is also cited to the effect that commercial R&D performed by a government agency alone might be inefficient (Hollomon, 1979, p. 32; Gilpin, 1976, p. 170). A team approach would establish a forum in which the parties concerned could discuss such problems at an early stage.

o A team approach to screening/evaluation would be effective as well, due to the screening of technologies which have no value for industry. In some recent literature on technology innovation, technology, etc., the need for a team effort to promote technology innovation and technology transfer has been identified and evaluated.

3.2 Disadvantages of a team approach to screening/evaluation.

Since the early sixties, government-industry relations--enforced mainly through regulation--have been of major concern

to both parties. All major firms now have at least one full-time Washington, D.C. representative. Industry does not passively accept government procedures. To the contrary, industry plays an active role. Established firms have large, and high-quality staffs dedicated to government relations. One of these tasks is to monitor government agencies' performance and to anticipate their future activities.

Keeping this in mind, it is rather naive to assume that industry would not use the possibility of a team approach to screening/evaluation to try to influence NASA's activities. A possible outcome would be the overidentification of NASA's work with industry's interest. Overidentification of government agencies with industries is a well-known fact. One opinion of the Federal Communications Commission (FCC) states that: "...the root of the FCC's problems is the agency's overidentification with the industries it regulates, its overidentification with the powerful and entrenched elements, in contrast to new and emerging facets or technologies, of the industries regulated" (Geller, 1975, p. 706). In this view, cause and effect are clearly described. Overidentification of a government agency with industry leads to a slowdown of technological advance. This is discussed in greater detail below.

o One of NASA's roles as a governmental R&D agency is to undertake R&D projects with high risk, long-term pay off, high social rate of return as compared to the private rate of return, etc. Normally, private industry is unlikely to engage in such projects. The lack of private sector initiative

in the development of communication satellite technology after 1972, when NASA's efforts were curtailed, is a case in point (see: Office of Science and Technology, 1978, p. 4).

- o Some of NASA's projects stem from high priority industry needs. For industry, NASA is a prime source of R&D funding. Potentially a team approach to screening/evaluation could be misused for "doing industry's work."

- o Also, the possibility of unfair technology transfer exists. If a team approach to screening/evaluation is established, NASA must offer the body of its knowledge to all participating parties.

- o The team approach will only work if an appropriate climate of confidence is created. Members might not express their thoughts if they are likely to read them in the newspapers. Therefore, the team approach might not work under the conditions within which government organizations must operate. Strictly speaking, the "protection of the public interest" is critical. But it is often claimed, for example, that labor unions and "consumer representatives" should join industry committees (see e.g.: Brown, 1970, p. 31). In the past, in connection with follow-up analysis of industry's use of IAC services, NASA has experienced industry's sensitivity to information. The team approach has the potential of indicating to NASA, which NASA generated technologies are of substantial interest to industry and thereby provides a most valuable basis from which NASA can make its information dissemination

program more effective. But if the necessary condition of confidence cannot be created, the value of a team approach to screening and evaluation will only be moderate.

o In establishing procedures where other parties join the planning and decision-making of a government organization, one must recognize that the non-governmental members of the team are likely to try to shift the risk of failure to the government agency. On the other hand, NASA cannot delegate its responsibility for secondary utilization of aerospace technology to the team. If the team approach is adopted, NASA must maintain the ultimate responsibility for technology transfer.

A team approach to screening/evaluation then has advantages as well as disadvantages. The disadvantages--at least most of those mentioned above--occur by an overidentification of NASA with industry's interests. Yet, this possibility seems unlikely. Government agencies can be put in two main categories; industry-oriented (e.g. FCC) and functionally-oriented, or crosscutting (e.g. EPA). While industry-oriented agencies may be captured by the interest of the industry they regulate, this may be less likely for functionally-oriented agencies (see also: Weidenbaum, 1978, p. 10). In the secondary utilization of aerospace technology, NASA can be described as a functionally-oriented agency, with the task of transferring technology to all non-aerospace industries. The possibility of being captured by the interests of a single non-aerospace industry exists but does not seem to be a real threat.

3.3 Review of a team approach to screening/evaluation.

Only a comprehensive analysis will indicate the advantages and disadvantages of a team approach to screening/evaluation of NASA generated technology. Critical to the success of such an approach is the organizational structure which provides the basis for cooperation between NASA and the participating parties:

- o Should other participating parties serve as an advisory board to provide suggestions and recommendations, leaving decisions to NASA?
- o Should NASA be only one party among many, that is to say should NASA have no special power concerning decisions?
- o Should NASA and other parties be bound together in an advisory board and the responsibility for decisions be given to another federal organization?

These and other organizational options should be comparatively analyzed.

The advantage of a team approach to screening/evaluation is provided through the direct participation of private and government organizations which influence the technology transfer process. It can be assumed that the team approach has particular potential when the operations are based upon people rather than on fixed procedures. Procedures, most valuable for routine tasks, are not appropriate to the exploration of the changing factors which influence technology transfer. But this pattern

is twofold, in being dependent on the capability of the individuals joining the team, the performance of team members is a source of potential success and failure. This should be taken into account, especially in the implementation phase. It might be effective for NASA--before announcing the implementation of its team approach to screening/evaluation--to very carefully select individuals who are both capable and willing to perform the task. This selection process might best be achieved through informal contacts, keeping publicity very low. Furthermore, in case this screening/evaluation method is adopted, NASA should resist any moves to demonstrate its potential before the team is stabilized; that is to say, not until all individuals joining the team have accepted their role within the team and a climate of confidence has been created.

4. Potential members for the team.

The intention of this section is to cite and briefly describe organizations which could participate in the team approach to the screening/evaluation. Once again, only a comprehensive analysis can provide in-depth insights.

o One source of participants are industry specific R&D institutes. Besides the R&D effort of specific firms, there are often R&D projects undertaken by all (or the most important) firms within an industry branch. In some industries those R&D activities are institutionalized in the form of R&D institutes, e.g. the Chemical Industry Institute of

Toxicology. This Institute is funded by the largest U.S. chemical companies and investigates the toxicology of non-proprietary chemicals (Hiss et al., 1975, p. 97). In West Germany the "Institut der Stahl- und Eisenindustrie," has performed important studies for the steel industry on the development of mathematical process models for control of blast-furnace processes.

Normally, such institutes know the characteristics of technologies already being used and those in research programs. This knowledge would be extremely useful in identifying those NASA technologies having potential value for a certain industry. Furthermore, such institutes might prove useful in aiding NASA's development of prototypes.

o Another valuable organization might be industry associations. Industry associations possess substantial knowledge about the R&D performance of the industry they represent. For example, the association of the chemical industry knows under which circumstances this industry will be willing to switch from coal to oil. Therefore, NASA is able to grasp "what is going on in industry" and to prepare appropriate transfer efforts at the right time. NASA might also gain knowledge about typical industry R&D policies. For example, in areas such as semiconductors, electronic sub-assemblies and scientific instruments, process innovations are not "manufacturer dominated" but "user dominated" (Hippel, 1976; Hippel, 1977, p. 60; Abernathy, Utterback, 1978, p. 42). In other industries, raw material suppliers or the producers

of capital goods might dominate innovative behavior. In processing such knowledge, NASA would enhance its ability to address the right target group with information about new technologies.

As mentioned earlier, NASA technology transfer managers may lack "commercial experience." With the help of industry associations NASA might be able to use commercial facts to provide useful value-added technological information.

o The possibility also exists that single firms might join the screening and evaluation process of NASA technology. At first glance, it seems that industry R&D line managers would be highly qualified to perform such work. But difficulties in selecting firms would undoubtedly arise. These difficulties can be avoided through the use of industry associations and professional societies.

o Professional societies might be a valuable organization for screening and evaluating NASA's technologies. In most cases such societies represent a substantial part of professionals working in a certain field, and they generally have good reputations. In some cases those societies already evaluate new technologies and offer education to their members concerning those technologies. Education is important. The mere existence of a technology is not sufficient; a capability to use it must be developed (Gee, 1978, p. 109).

In West Germany, starting in 1978, the ministry of science and technology realized the high potential value of

professional societies. The societies perform work similar to that of NASA's Industrial Application Centers.

In an investigation about "diffusion and utilization of scientific and technological knowledge within state and local governments" it is noted that professional engineering societies, e.g. the American Society for Mechanical Engineering, are interested in becoming involved in the area of technology transfer (Feller, Flanary, 1979, p. III-41).

o In some cases it might be worthwhile to think about the possibility of including certain government agencies in the screening and evaluation process, at least on a case-by-case basis. This is due to the fact that while technologies might improve productivity or dampen inflation, they might also have side-effects for health, safety, environment, etc.

The costs of determining if a new technology will obtain regulatory authority approval can be an important factor in the introduction of innovations in technology (Hollomon, 1979, p. 33; see also: Weidenbaum, 1978, p. 17-20). If the concerned government agencies participate in the proposed screening and evaluation process of new technologies, they could facilitate the innovation process. If regulatory information were added to the technical description of a new technology, a potential entrepreneur could more readily assess its commercial prospects.

o Organizations within the university community present another possibility. There are two groups of major importance,

scientific and technology utilization personnel. Professors are a very valuable group to have join the screening and evaluation process. Furthermore, in this case it is worthwhile to consider a secondary benefit of using universities. Universities are of substantial importance as a transfer medium and would link NASA directly to the professionals of tomorrow.

One might also think about university technology utilization personnel. In recent years university administrations have explored the revenue generating value of university generated inventions (Udell, Johnson, 1978, p. 175) and by now quite a few universities are active in this area.

Conclusions

Underlying the analysis in this paper is the assumption that the NASA technology transfer could be substantially improved if the application process of technologies were better understood. NASA is successful at information dissemination, but there is a lack of knowledge about why certain technologies are adopted and other technologies are not. A comprehensive understanding about factors influencing technology transfer might indicate ways of developing improvements. By including non-federal organizations, such as professional societies and industry R&D institutes, in the screening and evaluation process of NASA generated technology, opportunities may develop to enhance technology transfer from NASA to industry.

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